FIRST YEAR'S COURSE IN PRACTICAL PHYSICS

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JAMES SINCLAIR

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A FIRST YEAR'S COURSE IN PRACTICAL PHYSICS

BY

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PREFACE

THIS book is an attempt to provide for pupils in Day Schools, Evening Schools, and Pupil Teachers' Classes a course in Practical Physics which is not too difficult for young students, but which contains all that is really essential. All the experiments have been performed by my pupils during the last four years.

In most books on Practical Physics the experiments are surrounded by a considerable amount of theory. I think this is a mistake. All the theory should be given by the teacher, at least for the first year. The best way to teach the theory is to gather the pupils round the black-board at the beginning and at the end of an experiment, and discuss the experiment with them.

The experiments up to and including those on Pressure are sufficient to occupy three or four hours per week during a session of forty weeks, but as many teachers include Heat in the First Year's course I have added a chapter on that subject. It is not advisable to attempt too much in the first year. Dynamics, Heat, and Optics should be taken in the second or third year.

The exercises at the end of each experiment are numerous, and are intended (1) to afford practice in the main principles underlying the experiment, and (2) to provide work for those pupils who finish the experiment before their neighbours. It is best to keep all the pupils at the same experiment, and the exercises are an aid to this.

The careful recording of the experiments is of great importance in practical science, and a few hints may not be out of place.

1. The note-book should be large enough for all the records during a session, and should have a margin for the teacher's marks. At the end there should be a few pages of squared paper (say ten divided into $\frac{1}{10}''$ and ten into millimetres). If these are perforated they can be gummed on the page opposite that on which the experiment is written.

2. The record should be written *in ink* on the right-hand pages, and the left-hand pages reserved for tables and diagrams. Any rough work—*e.g.* calculations—should be done on a jotter. The writing in ink enforces accuracy. The pupil is compelled to think well before he writes, for he knows he cannot easily rub out what he has written. If there are no ink-wells in the laboratory the pupils should be asked to bring ordinary ink-bottles, which may be kept on the shelves.

3. Every experiment should be marked by the teacher before the pupil is allowed to commence the next experiment. If this is not done, some pupils will fall into a bad habit of leaving records unfinished. I have found it a good plan to give marks (say up to 10) for accuracy and neatness.

4. Diagrams of all the new apparatus used in the experiment should be drawn. If possible, the diagrams should be drawn from the object, and only when the object is very difficult to draw should the teacher draw it on the black-board.

5. If any experiment is very badly done, or if the record is untidy, the pupil should rewrite it on the following pages, and gum together the pages containing the bad work. If this is done no loose leaves are left.

6. For accurate measurement steel straight-edges are much better than those made of wood. The divisions are more accurate, the ends are not liable to become broken, and though the cost of the steel straight-edges is greater, they last much longer. A wooden straight-edge, for drawing lines, should be kept in the bench drawer, but it is safer to keep the steel straight-edges in the apparatus cupboard. An occasional rub with Brooke's soap will keep them from rusting.

The experiments are arranged in the order in which they are performed in my classes. I have tried, as far as possible, to have a logical sequence. For this reason I have not taken Mass till Volume has been studied. If the pupil is told at the introduction to Mass that the unit of mass (1 gramme) is derived from the unit of volume (1 c.c.) he feels he is not commencing an entirely new subject, and so the connection is preserved. It is unfortunate that the words "mass" and "weight" are so often used for the same thing, and that "weighing a body" is used to denote the process of finding either the weight or the mass. If the teacher explains the terms during the first lesson on weighing he will find that the pupils readily recognise the distinction.

In addition to the exercises at the end of each experiment I have given an examination paper on the work of each chapter.

My thanks are due to my friend, Mr George W. M'Allister, M.A., for his careful correction of the proof-sheets.

NOTE TO THE FOURTH EDITION

In preparing this edition I have availed myself of many suggestions made to me by teachers who are using the book in their classes, and I am specially indebted to Mr W. J. Mabbott, Rector of Berwickshire High School. Many of the experiments, up to and including those on Pressure, have been revised. The Chapter on Heat has been left as it was, since the subject is fully treated in the Second Year's Course. In the Appendix will be found several experiments on the Simple Pendulum, a note on Measurement of Area, and a set of Examples for Revision.

April, 1908.

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INSTRUCTIONS TO PUPILS

1. Accuracy and neatness are essential to good work. Never write anything on your note-book about which you have any doubt.

2. Write on the right hand pages of your note-book all your work as you do it. You should write in such a way that another pupil who had not done the experiment could perform it by following your record. Keep the left pages for tables and diagrams. Tabulate your results wherever possible.

3. Begin each experiment on a new page. Write the date at the head of the page on the margin. Number each experiment.

4. Leave two or three lines under the heading of the experiment. Write here a list of the apparatus as you use it.

5. Your writing should be your best. Do not hurry over the writing. Remember it is a part of the experiment.

6. Write any definitions or formulæ, which you wish to remember, on the left hand page opposite the experiment, and fill up the tables at the end of this book.

PRACTICAL PHYSICS

CHAPTER I

MEASUREMENT OF LENGTH

EXPERIMENT **1**

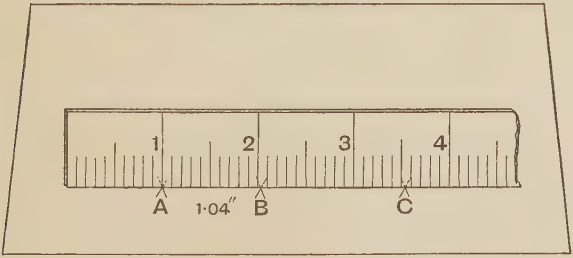
To find the Distance between Points

Apparatus—Steel Straight-edge.

On one of the lines of your note-book mark five points. One way of marking a point is to make one fine line cut the line of your book —┼—, or two fine lines intersect on the line of your book —×—. If the lines are very thin the point where they intersect has practically no size. Name the points A, B, C, D, E.

Measure the distances A-B, B-C, C-D, D-E, A-E in the following way:—

Place your straight-edge nearly at right angles to the paper,



with the graduated side away from you. This allows the marks on the straight-edge to touch the points on the paper so that you can read the length accurately.

Place the straight-edge so that an inch division mark is exactly at A. (See diagram.) Count the number of inches and tenths of an inch between A and B. In the diagram, B is between the tenth and the eleventh divisions, therefore A B is between 1·0 and 1·1 inches.

To get the second place of decimals divide the small division in which B lies into 10 equal parts. This is easily done with your eye. Count how many of these parts lie between the beginning of the division and B. In the diagram the number is 4. This equals $\frac{4}{10}$ of a division—that is, $\frac{4}{10}$ of $\frac{1}{10}$ inch, or ·04 inches. Adding this to the first answer, 1·0 inches, we get the exact distance to be 1·04 inches.

If the distance between any two points is an exact number of inches and tenths—*e.g.* 1 inch and 8 tenths—the answer should be written 1·80 inches, showing that the answer is correct to two places of decimals.

Measure the distances between the other points. The distance A-E should be equal to the sum of the other four.

Measure the distances also in centimetres. You should be able to get the answers correct to two places of decimals though the divisions are smaller. Arrange your results in a table. In the last column write the number of centimetres in 1 inch. To get this number proceed by proportion:

If 1·04 inches are equal to 2·66 cm., how many centimetres are equal to 1 inch? In getting the answers in the last column, carry the work one place farther than is required—*e.g.* if 2·538 is got, take 2·54 as the answer.

Points	Length in Inches	Length in Centimetres	Number of Cm. in 1 Inch
A – B	1·04 inches	2·66 cm.	...... cm.
B – C			
C – D			
D – E			
A – E			
		Mean =	

EXERCISES

1. Measure the distance between two points on a curved or uneven surface (*e.g.* a bottle) by stretching a piece of tracing-paper over the surface, marking the points on it, and proceeding as in Exp. 1.

2. Measure the perimeter of a page of your note-book in inches and centimetres. Test your answers by finding the number of centimetres in 1 inch.

3. Measure the length of your middle finger in centimetres and the span of your hand in inches. Remember these lengths.

4. What is meant by a fixed unit of length? Why is it necessary to have one? A farmer measures the length of a field by stepping it, and calling each step a yard. Can you give any other examples of units which are not a fixed length?

5. Draw a line $2\frac{7}{10}$ inches. Make it $3\frac{9}{10}$ inches longer. What is the length of the whole line in centimetres?

6. Measure the greatest length and breadth of England. Use the scale on your map.

EXPERIMENT 2

To find the Length of Given Straight Lines

Apparatus—Steel Straight-edge, Dividers.

Draw on your note-book three lines of unknown length.

First Method.—Measure the length by placing the straight-edge along the lines as in Exp. 1.

Second Method.—Measure the length by placing one point of a pair of dividers at the beginning of the line and the other point at the end. Now place the dividers on the straight-edge, the left point being placed at a centimetre division, and read off the distance between the points.

Arrange your results in a table as in Exp. 1.

Notes.—(1) When opening the dividers you will sometimes find that the legs spring back a little. Allow for this and make certain that the legs are really the exact distance apart.

(2) Hold the dividers at the top in such a way that the pressure of your fingers will not alter the distance between the legs.

Exercises

1. Find the number of inches in a metre by drawing a line of 1 decimetre length, measuring its length in inches, and multiplying by ten.

2. Draw lines of the following lengths:—

·175 metres, 1·16 dm., 5·24 cm.

Write the length in inches under each line.

3. Draw a line equal to the sum of 2·16 inches, 1·05 inches, and ·76 inch. What is its length in centimetres?

4. A merchant wishes to buy 70 yards of cloth from a French firm which sells only in metres. How many metres will he order?

5. Measure the length of your bench in feet and calculate its length in metres. Check your result by measurement.

6. Find the number of kilometres in a mile, if 1 metre = 39·37 ins.

7. Find how often the length of your pen goes into the length of your bench. What is your unit? Is it a good unit? Can you give any other variable units which are sometimes used?

8. Find how many centimetres are in 1 yard.

EXPERIMENT 2A

To draw a Graph which will read Centimetres and Inches

Since this is a graph of a fixed ratio the graph will be a straight line, and so only two points are required. As 0 cm. = 0 inches, the origin will be one of these points. Also 2·54 cm. = 1 inch, therefore 25·4 cm. = 10 inches, so the point (25·4, 10) will be another point. On squared paper draw the axes and choose the units so as to read (say) 50 cm. Plot the points (0, 0) and (25·4, 10). Draw a straight line through them. From the graph find how many inches are in 30 cm.

Exercises

1. Draw a graph to read metres and yards. Use it to find the answer of Ex. 4 in Exp. 2.

2. Test the answers of the exercises in Exp. 1 and 2 by the graphs.

EXPERIMENT **3**

Average of Measurements

Apparatus—Steel Straight-edge or Metre Stick, Thread.

Take a piece of thread, and with it measure the distance round your head. Measure four times, and take the average. Arrange thus:

First Measurement = ... cm.
Second ,, = ... cm.
Third ,, = ... cm.
Fourth ,, = ... cm.

Average Measurement = ... cm.

Note.—In the following experiments all measurements should be taken at least three times, and the average chosen as the answer, after rejecting any measurement which is obviously wrong.

EXERCISES

1. Find the average breadth of Ireland by drawing parallel lines across the map at equal distances (say every $\frac{1}{4}$ inch). Use the scale attached to your map.
2. Find the average height of the pupils in the class. [Work in pairs, each pupil measuring the other.]

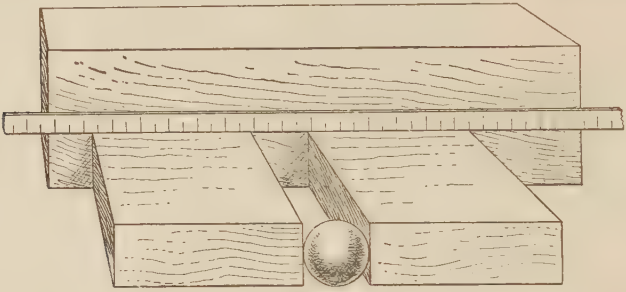
EXPERIMENT **4**

To find the Diameter of a Sphere

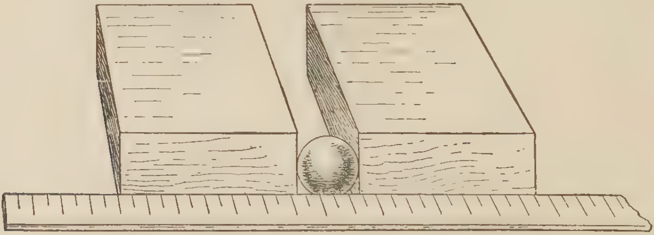
Apparatus—Wood or Glass Ball, three Wood Blocks, Straight-edge.

First Method.—Take two blocks of wood which are higher than the sphere, and test if they are rectangular by placing them together side by side. The sides in contact should touch at every point. Test all the sides.

Place the two blocks firmly against a third rectangular block as in the diagram. Place the sphere between the two blocks so that they touch it. Measure the perpendicular distance between the two blocks. Take the average of three measurements.



Second Method.—Place the straight-edge, two blocks, and sphere as in the diagram, and measure the distance between the two blocks, reading the answer from the straight-edge. Take three readings. Compare with the former result.



EXERCISES

1. Find the diameter, using a pair of ordinary calipers (The sphere should just pass between the points of the calipers.)

2. How would you find the diameter of a football?

3. Why must the blocks of wood used in the experiment be at least higher than half the height of the ball?

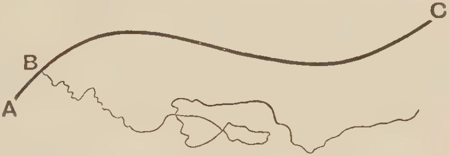
EXPERIMENT **5**

To find the Length of a Curved Line

First Method

Apparatus—Thread, Straight-edge.

Draw a curved line of any shape. Take a piece of thread, and place the end of the thread on the end of the line at A. Keep it fixed with a finger of your left hand, and with your right hand place about half-an-inch of the thread along the line (say to B). Now place another finger of your left hand at B, taking care that the thread does not slip away from A while you are doing it. Proceed in the same way till you reach C. Mark with your pen the part of the thread at C. Measure on your straight-edge the length of the thread which covers the curve. Repeat three times, and take the average.



Second Method

Apparatus—Dividers, Straight-edge.

Open a pair of dividers till the points are a short distance apart (say 3 mm.). Place one leg at the end of the curve, and, keeping it fixed, turn the dividers round that leg till the other leg is exactly on the curve. Repeat this till you have passed right along the curve. Multiply the number of times you have turned the dividers by the distance between the legs. This gives the length of the curve. Can you state any disadvantage in using this method?

Third Method

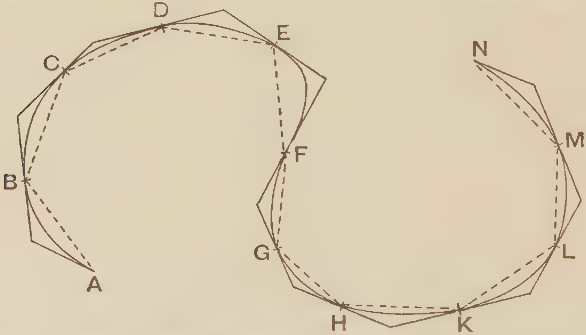
Apparatus—Tracing-wheel, Straight-edge.

Take a tracing-wheel, such as is used by dressmakers, and run it along a line on the left page of your note-book. Count thirty spaces between the marks of the teeth, measure this distance, and divide the answer by thirty. This gives the *average* distance between two successive teeth.

Run the tracing-wheel along the curve, count the number of spaces, and multiply the answer by the distance between two teeth. This gives the length of the curve.

Fourth Method

Mark points A, B, C, etc., along the curve, about 2 cm. apart, and join them by dotted lines. These lines are called *Chords*. Measure the length of each chord, and add the answers. At the marked points draw lines to touch the curve. These lines are called *Tangents*. Measure the length of each tangent, and add the lengths. The length of the curve is the mean of the two answers. Which is the shorter of the two sets of lines, and why? This method enables us to measure a curve without any instrument but a straight-edge.



Note.—In some curves one of the lines called tangents passes across the curve (*e.g.* the line through F). Notice how this line goes as far as possible in the same direction as the curve

Fifth Method

Apparatus—Pins, Thread, Straight-edge.

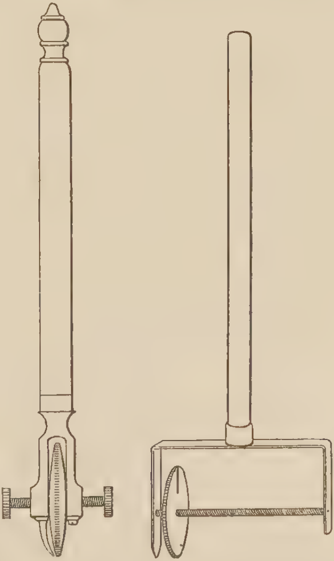
Place pins along the curve about $\frac{1}{8}$ through the paper at right angles to it, about ·5 cm. apart, and lay a piece of thread along the pins so that it covers the curve. The thread can be kept from slipping by winding it in and out among the pins. Mark with ink the thread at the ends of the curve. Measure the length of the part of the thread which covers the curve.

Sixth Method

Apparatus—Opisometer, Straight-edge.

Examine an opisometer. Turn the wheel until it is hard against the pointer. Hold the instrument vertical, with the pointer on the end of the curve, and run it along the line to the other end. Then place the pointer on the straight-edge, and run it *backward* till the wheel is again stopped by the pointer. Read off the distance travelled on the straight-edge.

In another form of opisometer the wheel turns round but it is the screw which moves forward. (See diagram.) The method of using is the same.



Exercises

1. Make a mark on the edge of a penny. Place the penny vertical, with this mark touching the beginning of the curved line. Run the penny along the curve to the other end, count-

ing the complete turns. Put another mark on the penny where it touches the end of the curve. Place the penny on a straight-edge, and run it along till it makes the same number of turns as before.

2. Find the distance between London and Newcastle—(*a*) by rail, (*b*) by boat, (*c*) as the crow flies. Use the scale on the map.

3. Find the length of the coast-line of England.

4. Do Ex. 1 of Exp. 1 by a different method.

5. Measure the length of a curved back of a chair.

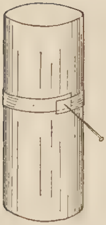
6. Find the length of the river nearest your town.

7. Find the average distance between your town and the town nearest it by different roads. [Use a map of the district.]

EXPERIMENT 6

To find the Ratio of the Circumference of a Circle to its Diameter

Apparatus—Four Wood Cylinders of different diameters (*e.g.* lead pencils, round rulers, etc.), Strips of Thin Paper, Pin, Blocks of Wood, Straight-edge.



First Method

Wrap a strip of thin paper round a cylinder till it overlaps. Prick a *fine* hole with a pin through the paper where it is double. Spread out the paper, and measure the distance between the two holes. This gives the length of the circumference.

Get the length of the diameter by blocks or calipers.

Do the same with other cylinders, and arrange your answers in a table.

Cylinder	Circumference	Diameter	$\frac{\text{Circumference}}{\text{Diameter}}$
No. 1	11·72 cm.	3·70 cm.	
,, 2			
,, 3			
,, 4			
		Mean =	

It will be found that the answer in the last column is always about the same. This number (3·14+) is denoted by the Greek letter π. Remember that π is a *number*, and stands for the number of times the diameter of a circle is contained in the circumference.

Second Method.

Wind a piece of thread five or six times round a cylinder, keeping the windings alongside one another. Measure the length of an exact number of windings, and so get the length of one, which is equal to the circumference. Measure the diameter as in Exp. 4. Arrange in a table as before.

Third Method.

Draw a circle on paper. Measure the circumference by any two of the methods of Exp. 5. Draw a large circle on the floor, and measure its circumference with a piece of string.

EXERCISES

1. If r represents the length of the radius of a circle, what will represent (*a*) the diameter, (*b*) the circumference, in terms of r?

2. Measure the diameter of a halfpenny in inches, and from it find the circumference.

3. A circular lake is half-a-mile in circumference. It is proposed to throw a bridge across it. What would be the greatest possible length of the bridge?

4. A bicycle wheel 28 inches diameter has a white patch

on the tyre. How often will the patch touch the ground during a ride of a mile?

5. A boy sitting behind a moving cab notes that the hind wheels turn 120 times. If the diameter of the wheel is 4 feet, how far has he travelled?

6. How would you find the diameter of the trunk of a tree?

7. The radius of the earth is nearly 4000 miles at the equator. How far do objects at the equator move in an hour?

8. A circle 25 cm. diameter just touches the sides of a square (*i.e.* the circle is inscribed in the square). Which has the shorter perimeter and by how much?

EXPERIMENT 6A

To draw a Graph of Circumference with Diameter

The circumference of a circle is equal to 3·14 times the diameter. Suppose we make the diameter equal to 1 c.m., 2 c.m., etc. Write the length of the circumference.

Diameter	1 cm.	2 cm.	5 cm.		
Circumference					

Plot the points. What is the shape of the graph? From the graph find the radius of a circle whose circumference is 25 cm.

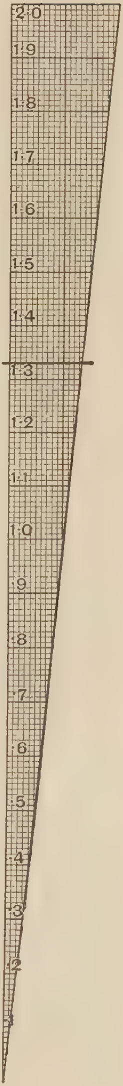
Note.—This graph can be drawn by plotting the values found in Experiment 6.

EXPERIMENT 7

To find the Outside Diameter, Inside Diameter, and Thickness of Glass Tubing

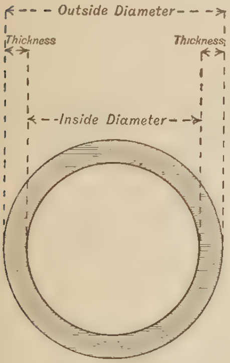
Apparatus—Outside and Inside Calipers, Glass Tubing, Sheet of Squared Paper, Scissors.

Cut a wedge of squared paper 20 cm. long and 2 cm. wide at the top. Measure the width at each centimetre division with your straight-edge, and mark it as in the diagram. Place the wedge in the glass tube, and note the breadth at the top of the tube.



Suppose the top of the tube is at the black mark. (See diagram.) The inside diameter of the tube is between 1·3 cm. and 1·4 cm. Between 1·3 and 1·4 there are ten equal divisions, and as the mark is at the third division from 1·3 the diameter is 1·33 cm. Take three or four measurements, turning the wedge in the tube, and find the average.

Test your result by using the inside calipers. Open them till they just go inside the tube and no more. Measure the distance on the straight-edge. Will this answer be as exact as the first answer?



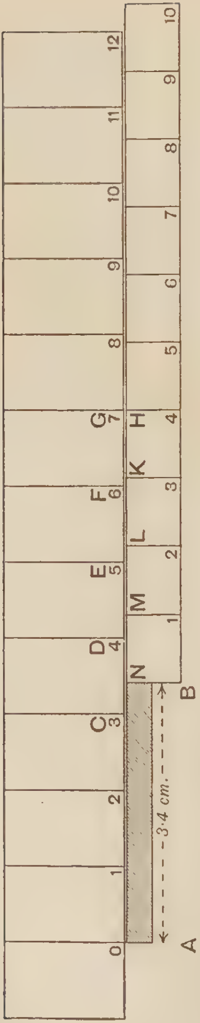
To get the outside diameter open the outside calipers till the tube will just pass between the points. Measure this distance on the straight-edge.

To get the thickness of the glass, subtract the inside diameter from the outside diameter, and divide the result by two. Why?

EXERCISES

1. Find the bore, thickness of metal, and outside and inside circumference of the tube of a bunsen burner.

2. Suppose the inside diameter of a tube were more than 2 cm., how would you make the wedge?



EXPERIMENT 8

Construction and Use of a Vernier Scale

Apparatus—Stiff Paper, Scissors, Straight-edge, Small Cylinder.

Cut a strip of stiff paper 9 cm. (exactly) in length and about 1 cm. in breadth. Divide it into ten equal parts by drawing lines across it (each part will be ·9 cm. long). This strip of paper is called a *Vernier.*

Place the cylinder so that one end (A) is exactly at a division of the centimetre scale on the straight-edge. Then place the vernier scale hard against the other end as in the diagram. Here it is seen that the length of the cylinder is 3 cm. and a part CN. To get the length of CN look along the vernier scale till you find a division on the two scales in the same straight line. Here the fourth on the vernier is in the same straight line as a division on the straight-edge.

Now

$$\begin{aligned}
FK &= GF - HK = 1\text{ cm.} - \cdot 9\text{ cm.} = \cdot 1\text{ cm.}\\
EL &= GE - HL = 2 \times 1\text{ cm.} - 2 \times \cdot 9\text{ cm.} = \cdot 2\text{ cm.}\\
DM &= GD - HM = 3 \times 1\text{ cm.} - 3 \times \cdot 9\text{ cm.} = \cdot 3\text{ cm.}\\
CN &= GC - HN = 4 \times 1\text{ cm.} - 4 \times \cdot 9\text{ cm.} = \cdot 4\text{ cm.}
\end{aligned}$$

Therefore the length of the cylinder is 3 cm. + ·4 cm. = 3·4 cm.

The rule, therefore, is as follows:—Look along the vernier scale till you find a division on it in a straight line with a division on the straight-edge. Count the number of spaces on the vernier between this line and the beginning of the vernier. This number gives the decimal in the length of the object.

In ordinary verniers the divisions are not ·9 cm., but ·9 mm. The method of working is the same, but the answer will be in millimetres. [The 'Columbus' slide calipers, which may be got from any dealer for a few shillings, is a very useful instrument when exact measurement by a vernier is required.]

Exercises

1. Find the exact length of the edge of a cube, the diameter of a sphere, the diameter of the base of a cone, using slide calipers with a vernier attached.
2. Find the exact height of the mercury in the barometer.

EXPERIMENT 9

Principle and Use of Micrometer Screw

Apparatus—Bolt and Nut, Straight-edge, Micrometer Screw, Hairs of different Colours.

Look at the bolt, and see if the distance between two successive threads is always the same. This distance is called the *Pitch* of the Screw. Along the top of the bolt and nut draw a line with pencil or chalk. Measure the length of ten pitches of the screw along this line, using your straight-edge. Divide the answer by ten, and so get the pitch.

Hold the nut in your hand, and turn the bolt round one complete turn. How many pitches has the bolt moved forward? Turn the bolt two turns, five turns, half a turn, etc. How many pitches has it moved forward? You will find the length moved forward or backward by the bolt by counting the number of turns and multiplying the pitch of the screw by this number.

Hold the point of the bolt against the wall. Turn the bolt backward through 3·5 turns. What is the distance between the point of the bolt and the wall?

Examine a micrometer screw. Screw out the bolt, and measure the pitch as above. You will likely find that the pitch is exactly 1 mm. Notice that the circumference of the bolt is divided into 100 divisions, so that you can measure ·01 of a turn.

Screw the bolt into the nut till it is *just* stopped. You will notice that opposite the mark 0 on the bolt there is a line on the nut. (If you find that the line on the nut is not exactly opposite the mark 0, ask your teacher to make the instrument true.) *Never turn the bolt beyond this.*

Now place a hair between the bolt and nut, and screw up the bolt till the hair is just caught. You should be able to draw the hair out with difficulty. Notice the number of the division on the bolt opposite the line on the nut. Suppose the number is 4. This means that the bolt has been turned backward $\frac{4}{100}$ of a turn. Therefore the distance moved backward by the bolt is $\frac{4}{100}$ of a pitch $= \frac{4}{100}$ of 1 mm. $=$ ·04 mm. $=$ ·004 cm.

Measure the diameter of hairs of different colours, and arrange the answers in columns.

Colour of Hair	Diameter at Root	Diameter at End

EXERCISES

1. Find the thickness of a sheet of paper, of a microscope slide, and the average thickness of a halfpenny.
2. Find the diameter of a wire, taking different readings by turning the wire.
3. Find the diameter of small shot.

EXAMINATION PAPER ON LENGTH (Exp. 1-9)

1. What is a unit of length? Give six units with which you could measure the height of a boy. Which are the best, and why? Is the length of your hand a good unit?

2. Define the British and the French Standard Units. Which is the better system?

3. You are given a steel straight-edge marked in inches and millimetres. How would you find the number of feet in a metre? What should the answer be?

4. Describe two methods of measuring the curved back of a chair.

5. Describe a method of measuring the length of a curved line, using no apparatus but a straight-edge and a pencil.

6. What is π? What number does it represent? How would you find that number?

7. The circumference of the bottom of a circular flower pot is 50·24 cm. A snail is placed at the centre. How long would it take to reach the edge, moving at the rate of ·01 cm. per minute?

8. Describe the instrument you would use to find the diameter of a pin.

9. Give two methods of finding the thickness of the glass at the mouth of a lemonade bottle.

10. You are given a tracing-wheel in which the teeth are not exactly the same distance apart. How would you find the average distance between two teeth next to each other?

11. A wooden trunk is 5 feet long, 2 feet broad, and 2 feet high. Its edges are covered with strips of sheet iron. What length of iron is used?

12. How many pins each 25 mm. long can be cut from a coil of wire ·5 km. in length, allowing 2 mm. extra for the head of each pin?

13. What is the advantage of a vernier? One is required to read ·1 mm. How must it be made? What divisions would be required on the straight-edge?

14. A nut on a bolt advances 5 cm. when turned 200 times. What is the pitch? The pitch of another bolt is ·015 cm. How far will it advance when turned 100 turns?

CHAPTER II

MEASUREMENT OF AREA[1]

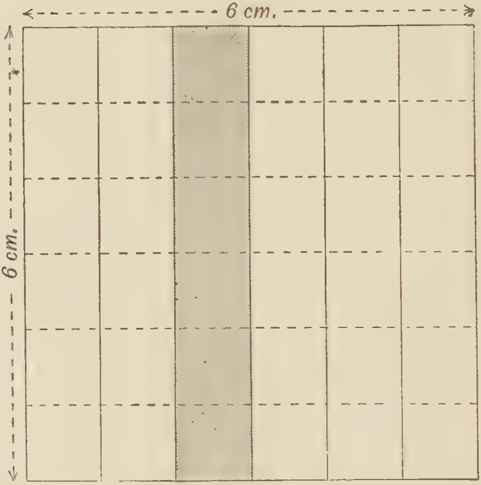
EXPERIMENT **10**

To find the Area of a Square

Apparatus—Straight-edge.

DRAW a square inch and a square centimetre side by side, and guess how many times the area of the square inch is as great as that of the square centimetre.

Draw a square of (say) 6 cm. side, marking off the centimetres. Join corresponding points as in the diagram. How many cm. are there in the length? How many rows of squares are there like the shaded row in the figure? If there were 10 cm. in the length, how many rows of squares would there be? How many cm. are there in the breadth? How many squares are there in each row? If there were 12 cm. in the breadth how many squares would there be in each row? How many squares are there in the whole figure? How could you get this number if you knew the length and breadth of the figure?



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[1] See *Note on Measurement of Area* in Appendix.

(Remember you are multiplying two numbers.) The result will give the number of square units in the large square.

For example, if the length of the square is 2 miles the area is (2 × 2) square miles; if the length is 3 metres the area is (3 × 3) square metres. (Distinguish between 9 square metres and 9 metres square.)

For convenience the rule is written thus:

Area = Length × Breadth.

Exercises

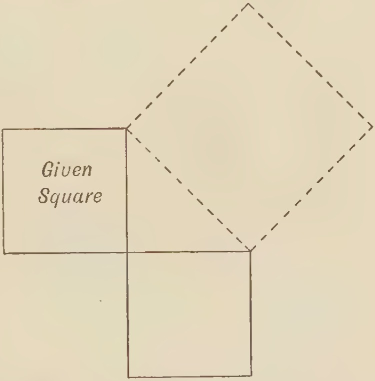
1. Using Exp. 10, find the exact number of sq. cm. in 1 sq. inch and the number of sq. mm. in 1 sq. cm.

2. Cut a square out of paper. Find its area (1) by measurement; (2) by using squared paper.

3. On squared paper draw a triangle ABC, having AC = 3 cm., BC = 4 cm., $\angle C = 90^\circ$. Measure AB. On the three sides draw squares. *Count* the number of square centimetres in each. Is there any relation between the answers? Repeat the exercise with any other right-angled triangle.

4. Using the result of Ex. 3, draw squares having areas 2, 3, 4, 5 times the area of a given square.

5. Using the result of Ex. 3, calculate the length of your bench from one corner to the opposite corner. Check by measurement.



6. Find the area of England by laying a piece of tracing-paper over a small map of England, and tracing the boundary. Transfer the trace to a sheet of squared paper, and count the number of square centimetres in the area. Look at the scale on the map. Measure how many centimetres represent 100 miles. From this find how many square centimetres represent 100 square miles. Then calculate the area of England in square miles.

[The area of your own parish or district may be found from the Ordnance Survey map.]

7. 100 square metres equal 1 *are*. Find how many ares are in a square field whose perimeter is 2 kilometres.

EXPERIMENT 11

To find the Area of a Rectangle

Apparatus—Straight-edge.

Draw a rectangle (say) 8 cm. in length and 6 cm. in breadth Join corresponding points, and, proceeding as in Exp. 10, get the rule for finding the area.

Write the rule in a handy form.

EXERCISES

1. Measure the area of a page of your note-book in sq. inches and sq. cm., and by proportion find the number of sq. cm. in 1 sq. inch.

2. 15 sq. yards of carpet are required to cover a floor. The length is 12 feet. What is the breadth?

3. A room is 20 feet long and 18 feet broad. What length of carpet 3 feet broad is required to cover the floor?

4. Find how many sq. feet of paper are required to cover the inside of one of the drawers in the bench.

5. The diameter of a halfpenny is 1 inch. How many halfpennies can be stamped from a rectangular sheet of metal 24·5 inches long and 16·25 inches broad?

6. Is it correct to say that the area of a floor 6 yards long and 8 feet broad is 48 units? Explain your answer, using a diagram.

7. A rectangle is 8 cm. long and 6 cm. broad. Its area is given as 16. Draw the rectangle so as to show the unit used, and name the unit.

8. Find the area of the wood frame of a blackboard (1) by dividing it into rectangles; (2) by taking it as the difference of two rectangles.

9. Draw a plan of the floor of the laboratory (or of the playground), and find the area of the part on which you can walk.

10. Round a bowling green (which is a square of 30 yards side) there is a path 3 feet wide. Find the area of the path by two methods. (See Ex. 8.)

11. A football pitch 100 yards by 50 yards has to be formed in the middle of a square field of $2\frac{1}{2}$ acres. What will be the distance between the touch-lines and the sides of the field?

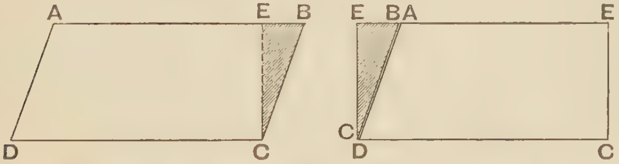
EXPERIMENT **12**

To find the Area of a Parallelogram

Apparatus—Straight-edge, Paper, Scissors, Gum.

Cut out of paper a parallelogram ABCD. Measure the length CD and the *perpendicular* height CE.

Cut along CE, and place the triangle BCE at the other end, as in the diagram. This gives a rectangle having the same area as the parallelogram. [Gum the paper on the left page of your note-book.]



The area of the rectangle = the length × the breadth. Measure the length and the breadth.

The length of the rectangle = the length of the parallelogram.

The breadth of the rectangle = the height of the parallelogram.

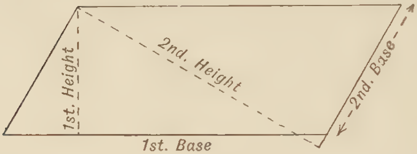
Therefore, to get the area of the parallelogram, multiply the length by the perpendicular height; or,

$$\text{Area} = \text{Length} \times \text{Height}.$$

Note.—The length is often called the *base*.

Exercises

1. Cut a parallelogram out of paper, and find its area (1) by measurement; (2) by squared paper. (In measuring take two adjacent sides in turn as the base, and note if the answers are the same.) Arrange thus—



Base = . . cm.
Height = . . cm.
∴ Area = . . sq. cm.

2. On the same base (or bases of the same length) draw two parallelograms having the same height. [Use squared paper.] Find their areas by counting the squares. Do the answers agree with what you expected?

3. The area of a parallelogram is 165 sq. cm. The height is 20 cm. What is the base?

4. Four sticks, two of them 8 cm. long and two 6 cm. long, are jointed together so as to form a movable parallelogram. What is the greatest and what the least area of the parallelogram?

EXPERIMENT **13**

To find the Area of a Triangle

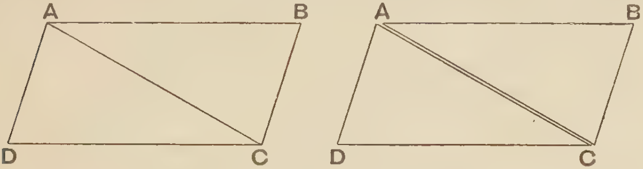
Apparatus—Straight-edge, Paper, Scissors, Gum.

Cut a parallelogram ABCD out of paper. Measure the base and the height.

Join the points AC, and cut along the diagonal AC. This gives two triangles. Place one on the top of the other, and so find if they are equal.

Measure the base and the height of each triangle, and compare with the base and the height of the parallelogram. Are they equal? From Exp. 12 you know that Area of

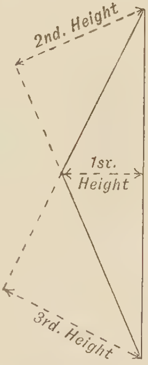
Parallelogram = Base × Height. You have found that the area of each triangle is half the area of a parallelogram having an equal base and equal height. Write down the rule for finding the Area of a Triangle.



Paste the two triangles on the left page of your note-book in the position shown in the figure.

Exercises

1. Draw any triangle, and measure its area three times, taking each side in turn as base. Write the answers in columns.



2. Measure the perimeter and the area of all the sides of the given block [half-a-cube].

3. Draw two triangles each of area 24 sq. cm.

4. Find the area of the surface of a pyramid.

5. Draw a triangle ABC, having $AC = 5$ cm., $BC = 12$ cm., $\angle C = 90^\circ$. Find its area and the area of the square on AB. [Use squared paper.]

6. The area of a triangle whose base is 1·5 cm. is 25 sq. cm. What is its height?

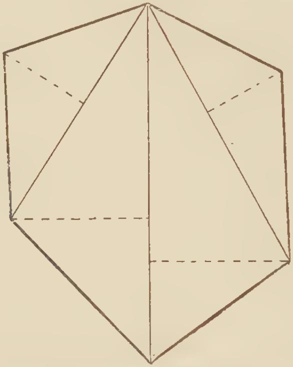
7. The area of a triangle is 16·03 sq. cm. The sides are 12·05 cm., 8·95 cm., 4·40 cm. Find the length of the perpendicular heights, and verify your answers by measurement.

EXPERIMENT 14

To find the Area of any Rectilineal Figure

Apparatus—Straight-edge, Tracing-paper.

Divide the figure into triangles by drawing lines from one corner to all the other corners. Find the area of all the triangles twice, by taking two sides as base, so checking your answers, and add the answers. Arrange in a table, thus:



	Base	Height	Area $= \frac{\text{Base} \times \text{Height}}{2}$
1st Triangle	...... cm.	...... cm.	...... sq. cm.
2nd ,,			
......			
Total Area			...... sq. cm.

Make a trace of the figure on tracing-paper, and transfer it to a sheet of squared paper (or make a trace of the figure on squared paper by pricking through the corners). Count the squares, and so find the area of the figure. Compare with first result.

EXERCISES

1. Find the area of a figure with curved sides. [Use squared paper.]

2. Find the area of a hexagon.

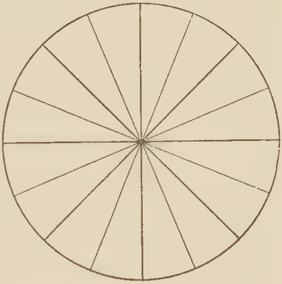
3. Find the area of a trapezium, parallel sides being 10·6 cm. and 7·4 cm. respectively, perpendicular distance between the parallel sides, 4·3 cm.

EXPERIMENT **15**

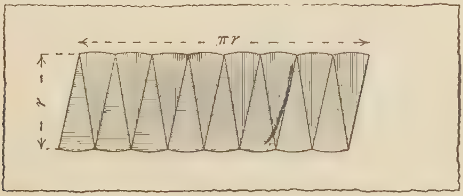
To find the Area of a Circle

Apparatus—Straight-edge, Paper, Scissors, 1 lb. Jam Pot Covers.

Get a circular jam pot cover (gummed on one side), and through the centre (got by folding the circle twice) draw diameters so as to divide the circle into sixteen equal parts. Cut along these diameters, and paste the parts along a line on a sheet of paper so as to form a parallelogram. The area of this parallelogram is the same as the area of the circle.



By Exp. 12 the area of a parallelogram = base × height. The base of the parallelogram is half the circumference of the circle [why?] By Exp. 6 (Ex. 1) the circumference of a circle $= 2\ \pi\ r$ where r is the radius; therefore the base of the parallelogram $= \frac{1}{2}$ of $2\ \pi\ r = \pi\ r$.



The height of the parallelogram is equal to the radius (r) of the circle.

$$\begin{aligned} \therefore \text{Area of Circle} &= \text{Area of Parallelogram} \\ &= \text{Base} \times \text{Height} \\ &= \tfrac{1}{2}\,\text{Circumference} \times \text{Height} \\ &= \pi r \times r \\ &= \pi r^2 \end{aligned}$$

Paste the sheet of paper on the left page of your note-book.

EXERCISES

1. Cut a circle out of paper, and find its area (1) using result of Exp. 15; (2) using squared paper.

2. Find the area of a halfpenny and the area of a square which just encloses it. How many square centimetres of copper remain after the maximum number of halfpennies have been stamped from a sheet of copper 9 cm. by 12 cm.? (See Exp. 11, Ex. 5.)

3. Find the area of the cross-section of a wire.

4. Find the diameter of a circle of area 300 sq. cm., and the area of a circle whose circumference is ·5 km.

5. Find the area of a semicircle and of a sector of a circle. [Area of Sector = $\frac{1}{2}$ (Part of Circumference of Circle in Sector) × Radius].

6. Find the areas of four circles of 5 cm., 10 cm., 15 cm., 20 cm. diameter respectively. Draw a graph of your results, and use it to find the area of a circle of 13 cm. diameter and the diameter of a circle of area 300 sq. cm. (See Ex. 4.)

7. Draw a square. Construct a circle of the same area. Find the value of the ratio $\frac{\text{Perimeter of Square}}{\text{Circumference of Circle}}$. Is this ratio constant in all similar cases?

EXPERIMENT **16**

To find the Total Surface Area of a Cylinder

Apparatus—Straight-edge, Slide Calipers, Paper, Scissors.

Find the area of the circular end, using the slide calipers to find the diameter. Arrange thus:

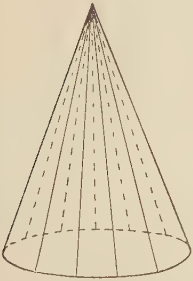
Diameter = ... cm.
$\therefore$ Radius = ... cm.
$\therefore$ (Radius)^2 = ... sq. cm.
$\therefore$ Area $= \pi r^2$ = ... sq. cm.
$\therefore$ Area of two equal Circular Ends = ... sq. cm. (1)

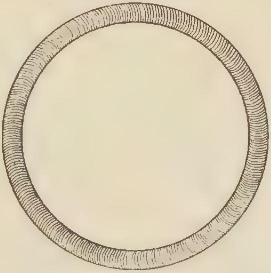
To find the area of the curved surface, cover the surface with a piece of paper. Cut the paper till it covers the surface exactly. On spreading the paper out flat you will see it is a rectangle, the length being equal to the circumference of the cylinder, and the breadth being equal to the height of the cylinder. Find the area of the rectangle.

Curved Surface is a Rectangle.
$\therefore$ Area of Surface = Area of Rectangle
= Length × Breadth
= Circumference × Height
= ...... cm. × ...... cm.
= ...... sq. cm. (2)
$\therefore$ Total Area of Surface = (1) + (2).

EXERCISES

1. Find the total surface area of a cone (1) by covering the curved surface with paper; (2) by dividing the curved surface into triangles and summing their areas.





2. Find the surface area of a circular anchor ring.

3. You are asked to find the surface area of a large cylindrical boiler. Would you cover it with paper?

EXPERIMENT 17

To find the Area of a Flat Ring

Apparatus—Flat Iron Washer, Wedge, Slide Calipers.

The area of the ring is the difference of the areas of the outer and inner circles. Find the diameter of the outer circle, using the slide calipers, and the diameter of the inner circle, using a wedge of stiff paper. Arrange thus:

Outer Circle	Inner Circle
Diameter = ... cm.	Diameter = ... cm.
∴ Radius = ... cm.	∴ Radius = ... cm.
∴ Area (πr^2) = ... sq. cm. I	∴ Area (πr^2) = ... sq. cm. II

∴ Area of Ring = I – II.

Test the accuracy of your result by placing the ring on squared paper, drawing the circles, and counting the small squares.

Exercises

1. A circular racing track has the following dimensions:—outside diameter 540 feet, inside diameter 500 feet. The track is covered with turf at 1s. per sq. yard. Find the cost.

2. Two men run once round the track. The outside man must keep a yard out from the inside man, who runs along the inner edge. Which travels the longer distance, and by how much?

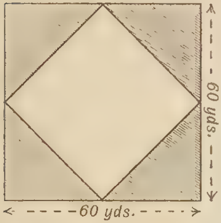
EXAMINATION PAPER ON AREA (Exp. 10-17)

1. In figure 1 the shaded portion is to be covered with concrete at 2s. per sq. yard. Find the cost.

2. If r denotes the radius of a circle, how would you denote the diameter, the circumference, and the area?

3. Explain how you would find the area of the cross-section of a wire.

4. The diagram 2 represents a trapezium. What is its area?



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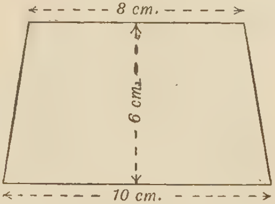


2

If a boy gave the answer as 13·5, draw and name his unit.

5. An irregular figure has curved sides. How would you find its area?

6. Draw a graph to read the radius and area of a circle. Use it to find the diameter of a circle whose area is 30 sq. cm.

7. A science note-book measures 22 cm. by 18 cm. by 1·5 cm. How many postage stamps 2 cm. by 1·5 cm. will it take to cover the outside of the book (so that the book may still be opened)?

8. How would you find the circumference and the area of the curved surface of an uncut pencil?

9. The perimeter of a square field is half-a-mile. What is the area of the field?

10. The circumference of a circular pond is 300 yards. What is the area of the pond?

11. The door of a house contains four rectangular glass panels each 20 inches long and 15 inches broad. A boy breaks two of them. How much must he pay, glass costing $10\frac{1}{2}$d. per square foot?

12. In a garden 200 yards square there are 4 equal circular flower plots 20 yards diameter and 2 equal square flower plots 30 yards side. The rest of the garden is in grass. Find the area of the grass portion.

CHAPTER III

MEASUREMENT OF VOLUME

EXPERIMENT **18**

Volume of Regular Solids

Apparatus—Boxes of small equal Cubes (*e.g.* Kindergarten Gifts of 1-inch edge).

TAKE five cubes, and put them in a row (Diagram 1).

Make five similar rows, and place them together (Diagram 2). You have now what is called a layer or slice.

Make five similar slices, and place them one above another (Diagram 3). You have now a large cube made of small cubes.

Measure the height. If the height is 5 inches, how many slices are there? What does the height tell you?

Take one slice, and measure its length. Is it the same as the length of the cube? If the length is 5 inches, how many rows of cubes are there in one slice? What does the length tell you? Can you now say what the breadth tells you?

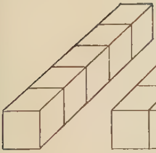
To get the number of small cubes in the large cube you take the number in one row, and multiply by the number of rows. This gives the number of cubes in one slice. Multiply this answer by the number of slices. Can you now write down the method of finding the volume of a cube?

Can the method be written thus:

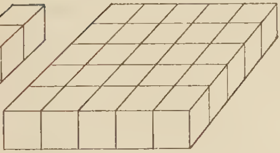
$$\text{Volume} = \text{Length} \times \text{Breadth} \times \text{Height ?}$$

Look at the base of the large cube. What is its shape? How would you find its area?

Hence Volume of a Cube = Base × Height.



1



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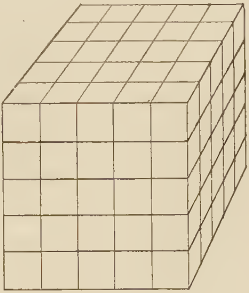


3

Build a square prism with the small cubes. Is the rule the same as before?

Repeat the experiment with a rectangular prism.

EXPERIMENT **19**

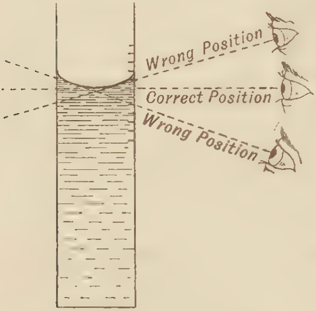
To test if the Graduations on a Measuring Jar are Correct

Apparatus—Several cubic centimetres of Metal, Graduated Jar, Burette.

Examine one of the small cubes given you. Count the number of edges, and measure them.

Examine a graduated jar. Notice that the graduations are at nearly the same distance. Measure this distance. Is it an exact number of centimetres?

Pour water into the jar. (In taking any reading, keep the jar vertical by placing it on the bench. Never read while the jar is in the hand.) Notice that at the top of the water there appears to be a ring which is lower at the centre than at the edge. This concave ring is called the *Meniscus.* In measuring the volume of water we measure from the bottom of the meniscus. Place the eye in the three positions shown in the diagram. [The graduation marks can be seen more distinctly if a piece of white paper is placed behind the jar.] Do you always get the same reading? *Remember that the eye must be on a level with the bottom of the meniscus.*



Pour water into the jar till the meniscus is at 50. Gently slip in one of the cubic centimetres of metal. How much does the water rise? Slip in other two or three cubic centimetres of metal. What then do the marks on the jar indicate? Have they anything to do with length? If the reading is 50, how many cubic centimetres of water are in the jar?

With different volumes of water in the jar, slip in cubic centimetres of metal, and note if the water rises a corresponding number of marks.

Next examine a burette. Notice that the whole tube is not graduated, therefore, when measuring, you must not allow the water to go above or below the graduated part. You will see that the numbers read downwards, unlike those on the graduated jar. Test the marks by running water from the burette into a graduated jar, and you will find that the volume between two successive long marks is 1 cubic centimetre (1 c.c.). As this space is divided into ten equal divisions you are able to read to ·1 c.c.

Exercise

Find the number of drops in 1 c.c. of water. Compare your answer with that of your neighbour. Is the volume of a drop of water always the same?

EXPERIMENT **20**

To find the Capacity of a Flask (or Jar)

Apparatus—Graduated Jar, Burette.

Fill a graduated jar to the mark 100, and pour the water carefully into the flask. As the flask gets filled let the water drop in till one drop more runs over the edge of the flask. Note the volume of water left in the jar. Subtract this number from 100, and the result gives the capacity of the flask in cubic centimetres. If the flask holds more than 100 c.c., fill the graduated jar a second time, and proceed as above.

Test the result, using a burette. Fill the burette to the mark 0. Put the flask underneath, turn the tap, and let the water run into the flask till the meniscus is at the mark 50. How many cubic centimetres of water are now in the flask? Fill the burette again to the mark 0, and proceed as before. When the flask is nearly full let the water drip into it till one drop more runs over the edge. Note the number of c.c. which have been run into the flask.

This answer is not exact. You must take into account the drop which ran over. Turn the tap till several drops of water fall. Count the number of drops. Note the reading on the burette, and so get the volume of one drop. Subtract this answer from the first result. Does this drop make any practical difference in the result?

Note.—The marks on the burette often become indistinct owing to dust getting into the burette. To prevent this plug the top of the burette with a piece of cotton wool at the end of each lesson.

EXERCISES

1. If the burette tube had not the same diameter at every point, what would you notice about the graduation marks?
2. Find how many cubic centimetres are equal to one pint.

EXPERIMENT **21**

To find the Volume of a Solid (*e.g.* a Stone)[1]

First Method

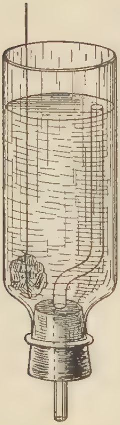
Apparatus—Graduated Jar or Burette, Thread.

Fill a graduated jar to the mark 50. Tie a thread to the stone, and lower the stone into the water. Note the reading. Arrange thus:

Volume of water at first = ... c.c.
Volume of water + stone = ... c.c.
∴ Volume of stone = ... c.c.

Second Method

Apparatus—Eureka Can, Beaker, Thread, Burette.



Fill a Eureka Can with water till the water runs out of the spout. Let it stand till the water stops dripping. Place a dry beaker under the spout, lower the stone by a thread into the water, and wait till the water stops dripping. The volume of water in the beaker is equal to the volume of the stone, because the water has been displaced by the stone. Find the volume of the water, using a burette. Fill the burette with water to a certain mark. Pour in the water from the beaker. Note the new reading.

Reading of water in burette, before, = ...
" " " after, = ...
∴ Volume of stone = ... c.c.

Another instrument which is sometimes used instead of the Eureka Can is the Displacement Cup. (See diagram.) The method of using it is the same as for the Eureka Can.

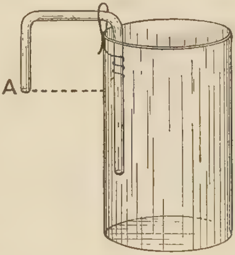
---

[1] In finding the volume of a body use the narrowest vessel possible, beginning with the burette.

Third Method

Apparatus—Jar, Syphon with Clip for fastening to Jar, Beaker, Thread.

Fit a syphon on to a jar, with the longer arm in the jar. Fill the jar with water till the level is above A. Suck at A, and the water will come along the syphon, and drop from A. Wait till the water stops dropping. What is the level of the water in the jar? Place a dry beaker under A, and slip the stone gently into the jar. When the water stops dropping from A measure in a burette the volume of the water in the beaker. What is the level of the water in the jar at the end of the experiment?



Fourth Method

Apparatus—Beaker, Burette.

Find the capacity of a dry beaker (Exp. 20). Dry the beaker again, place the stone in it, and find the capacity.

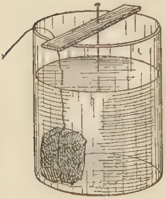
Capacity of beaker first time = ... c.c.
,, ,, second ,, = ... c.c.
∴ Volume of stone = ... c.c.

Fifth Method

Apparatus—Long, narrow Beaker or Jar, Burette, Piece of Wood with Needle stuck through it.

Place a flat piece of wood (a straight-edge will do) with a needle or pin stuck through it across the top of the beaker, which should be narrow, and contain water to within half-an-inch of the point of the needle. Place a burette above the beaker. Lower the stone into the beaker with a thread. (The water should not reach the needle.)

Very carefully run water from the burette till the needle just touches the surface of the water. This is best found by noticing when the reflection of the point in the water touches the real point. Note the reading of the burette. Lift the stone out of the water, and let it drip well before you remove it from the beaker. The level of the water in the beaker falls. Run water again from the burette till the needle touches the water. Read the burette. What is the volume of the stone?



If you wish to be very exact, you must take into account the small amount of water which is carried away by the stone. To find this, run water into the beaker to touch the needle, and note the reading. Lower the dry stone into the water, lift the stone out, and let it drip before removing. Since the stone carries away some water, the water in the beaker will not now touch the needle. Carefully run water from the burette into the beaker till the water touches the needle. Note how much water has been run in. What is the volume of the water carried away by the stone? What is the exact volume of the stone?

Which of the methods do you consider the best?

EXPERIMENT **22**

To find the Volume of a Body that Floats

Apparatus—Piece of Wood (or Cork), Stone heavy enough to sink the Wood, Apparatus of Exp. 21

Find the volume of the stone (which is called the sinker) by two of the methods of Exp. 21. Tie the stone and the wood together, and find the volume of the two. The thread connecting them should be short, so that the wood will be dragged under the water by the stone.

Volume of sinker = ... c.c.
Volume of sinker + wood = ... c.c.
∴ Volume of wood = ... c.c.

EXPERIMENT **23**

To find the Volume of a Piece of Wire

Apparatus—Burette.

Fill a burette to a certain mark. Straighten or fold the wire so that it will slip easily into the burette. Slip the wire gently into the burette, tap the burette gently to get rid of any bubbles of air which may collect on the wire, and note the new reading. (A piece of fine thread may be attached to the wire to lift it out of the burette.)

First reading = ... c.c.
Second reading = ... c.c.
∴ Volume of wire = ... c.c.

EXERCISE

Find the volume of a pin or a needle. [Take ten or twenty equal pins or needles.]

EXPERIMENT **24**

To find the Volume of an Insoluble Powder

Apparatus—Sand, Burette, Pipette holding 10 c.c. of Water.

Fill the burette to the mark 50. Pour the sand into the burette, using a paper funnel, and taking care that none of the sand is spilt. Tap the burette gently to get as much sand as possible under the water. Examine a pipette, and fill one with water up to the mark.[1] With this water wash the sides of the burette so as to get all the sand under the water in the burette. Suppose you have to fill the pipette three times, then you have added 3 × 10 c.c. of water. Note the reading on the burette. Suppose it is 5.

Reading before = 50
,, after = 5
∴ Increase of volume = 45 c.c.

∴ Volume of sand + volume of water added from pipette = 45 c.c.,

but volume of water added = 30 c.c.
∴ Volume of sand = 15 c.c.

EXPERIMENT **25**

To find the Volume of a Soluble Powder

Apparatus—Salt, Burette, Pipette, Beaker.

Put some water into a beaker, and add salt till no more will dissolve. Fill the burette with this salt water to the mark 50, pour in the salt whose volume is to be found, and proceed as in Exp. 24, but use the salt water for washing.

Note.—This experiment can be done in the same way as Exp. 24 by using a liquid in which the powder is insoluble.

---

[1] To fill a pipette, dip the bottom under water, and suck the water up a good bit above the mark. Without removing the bottom end from the water, place the finger quickly over the top end. The water should be above the mark. Now place a finger on the bottom end, and remove the first finger from the top end. Replace the first finger on the top end, and remove finger from the bottom end. You will notice that the water has fallen slightly. Repeat this till the water falls to the mark.

EXPERIMENT 26

To find the Volume of a Cube

Apparatus—Same as Exp. 21 or 22.

First Method.—By displacement. Find the volume by two of the methods of Exp. 21 or 22.

Second Method.—By measurement. Measure the length, breadth, and height.

Length = …… cm.
Breadth = …… cm.
Height = …… cm.

Volume = Length × Breadth × Height (see Exp. 18).
Compare the two answers.

= (… × … × …) c.c.
= … c.c.

Exercises

1. Find how many cubic centimetres are in 1 cubic inch. Draw the two cubes.
2. How many cubic centimetres are in (*a*) 1 cubic decimetre (this is called a *litre*); (*b*) 1 cubic metre; (*c*) 1 cubic millimetre?

EXPERIMENT 27

To find the Volume of a Square Prism

Apparatus—Same as Exp. 21 or 22.

First Method.—By displacement.

Second Method.—By measurement.
Perform the experiment in the same way as Exp. 26.

Exercise

A stack of bricks is 100 feet long, 20 feet broad, and 20 feet high. Each brick is 12 inches long, 6 inches broad, and 6 inches high. How many bricks are there in the stack?

EXPERIMENT **28**

To find the Volume of a Square Pyramid

Apparatus—Square Prism and Square Pyramid having equal Bases and equal Heights, Apparatus for Exp. 21 or 22.

Find the volumes of the prism and the pyramid by displacement. What is the value of the fraction $\frac{\text{Volume of Prism}}{\text{Volume of Pyramid}}$? 1/3

The volume of the prism = Base × Height. How would you write the volume of the pyramid?

Find the volume of the pyramid by measurement, and compare with the volume got by displacement.

Exercises

1. Find the volume of a rectangular prism and pyramid.

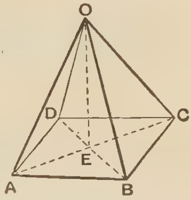
2. Find the volume of a triangular prism and pyramid. [*Note.*—In a triangular prism the volume is not equal to Length × Breadth × Height, for the Base = $\frac{1}{2}$(Length × Breadth). See Exp. 13.]

3. A chalk box is 20 cm. by 10 cm. by 10 cm. How many cubic centimetres of chalk can it hold? If the chalk is tightly packed in sawdust, how could you find the volume of the sawdust?

4. Find the volume of a sloping prism (or pyramid) by displacement. Measure the base and the *perpendicular* height. Does the product of these give the volume?

5. A square pyramid is 10 cm. long and 10 cm. high measured along an edge. Find the volume. [The perpendicular height OE must be found. Find AC. ($AB^2 + BC^2 = AC^2$). $AC = 2AE$. $AO^2 = AE^2 + OE^2$.]

6. A square pyramid is 10 cm. long and 10 cm. high, the height being measured from the middle point of a side of the base to the apex. Find the volume. Compare with Ex. 5.



EXPERIMENT **29**

To find the Volume of a Cylinder

Apparatus—Same as Exp. 21 or 22.

First Method.—Find the volume of the cylinder by displacement by two of the methods of Exp. 21.

Second Method.—If a cube or a prism be cut across parallel to the base the shape and area of the cross-section are always the same as the base. This is also the case with a cylinder, so it is possible that the volume of a cylinder, like the volume of a cube or a prism, may be got by multiplying the base by the height. Try this:

Volume = Base × Height
Base is a Circle
∴ Base = πr^2 (Exp. 15)
Diameter = ... cm. (see Exp. 4)
∴ r = ... cm.
∴ πr^2 = ... sq. cm.
Height = ... cm.
∴ Volume = ... c.c.

Is the answer got equal to the answer by the First Method?

Exercise

Measure the volume of a graduated jar between the marks 30 and 50 by finding the diameter of the jar and the distance between the marks.

EXPERIMENT **30**

To find the Volume of a Cone

Apparatus—Cylinder and Cone having equal bases and equal heights, Apparatus of Exp. 21 or 22.

First Method.—Find the volumes of the cylinder and of the cone by displacement, and get the value of the fraction $\frac{\text{Volume of Cylinder}}{\text{Volume of Cone}}$. $= \frac{1}{3}$/ base × ht

The volume of the Cylinder = Base × Height. How would you write the volume of the cone?

Second Method.—Find the volume of the cone by measurement, and compare with the answer got by displacement.

Note.—The cylinder need not be given, but its measurements may be got from the cone.

Exercises

1. A cone has a diameter of 10 cm. and a height of 15 cm. The top is sliced off parallel to the base at a height of 10 cm. from the base. Draw the solid which is left, and find its volume.
2. How would you find the volume of a sloping cylinder or cone?
3. The diameter of a cone is 6 cm. and the sloping height is 12 cm. Find the volume. (See Exp. 28, Ex. 5.)

EXPERIMENT **31**

To find the Volume of a Sphere

Apparatus—Same as Exp. 21 or 22.

First Method.—Find the volume by displacement, as in previous experiments.

Second Method.—The formula for finding the volume of a sphere is:

Volume $= \frac{4}{3} \pi r^3$ where r is the radius.

Find the diameter of the sphere by the methods of Exp. 4, or by the slide calipers, and arrange thus:

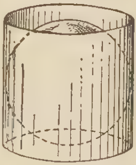
Diameter = ... cm.
∴ Radius (r) = ... cm.
∴ r^3 = ... c.c.
∴ Volume $= \frac{4}{3} \pi r^3$ = ... c.c.

Note.—The volume of a sphere and of its circumscribing cylinder (see Ex. 2) may be got by displacement, and from this the formula for volume of sphere $= \frac{2}{3} (\pi r^2 \times 2r)$, may be obtained.

EXERCISES

1. A balloon is 20 feet in diameter. How many cubic feet of gas can it contain?

2. A cylinder and a sphere have the same diameter and the same height (*i.e.* the cylinder can just enclose the sphere). Using the formulæ got in Exp. 29 and 31, find the value of the fraction $\frac{\text{Volume of Sphere}}{\text{Volume of enclosing Cylinder}}$. Test your answer by finding the volumes by displacement.



3. Find the volume of a spherical pellet of shot. [Find the volume of 50 equal pellets by the burette.] Check the answer by measurement, using a micrometer screw to get the diameter.

4. The volume of a sphere is 350 c.c. Find the diameter. [Draw a graph of r and $\frac{4}{3} \pi r^3$.]

EXPERIMENT **32**

To find the Diameter of a Cylindrical Jar from the Volume of Water it contains

Apparatus—Straight-edge, Graduated Jar.

Measure the inside height of the jar. Find the volume of water it holds, using the graduated jar.

Since the volume of a cylinder = Base × Height.

$$\therefore \text{Base} = \frac{\text{Volume}}{\text{Height}}.$$

Find the base.
But the base is a circle = πr^2.
Divide by π (3·14), and the answer equals r^2.
Take the square root. The result is the radius.
Arrange thus :

$$\frac{\text{Volume}}{\text{Height}} = \text{Base} = \pi r^2 = \ldots\ldots \text{ sq. cm.}$$

$$\therefore r^2 = \ldots\ldots \text{ sq. cm.}$$

$$\therefore r = \ldots\ldots \text{ cm.}$$

$$\therefore \text{Diameter} = 2r = \ldots\ldots \text{ cm.}$$

Test your answer by a wedge (Exp. 7).

EXPERIMENT 33

To find the Diameter of a Wire from its Length and Volume

Apparatus—Straight-edge, Burette, Micrometer Screw.

Find the length of the wire by the straight-edge and its volume by the burette. Since the wire is a long cylinder, Volume = Base × Height.

$$\therefore \text{Base} = \frac{\text{Volume}}{\text{Height}}.$$

Proceed as in Exp. 32.
Check the result by the micrometer screw.

Exercise

You are given an entangled piece of wire which cannot be uncoiled. How would you find its length? [Wire is a cylinder. Find its volume by a burette and its diameter (and so get the base) by a micrometer screw.]

EXPERIMENT **34**

To find the Thickness of a Sheet of Metal

Apparatus—Scissors, Straight-edge, Burette, Micrometer Screw.

If the sheet is not rectangular, cut a large rectangular piece. The sheet is now a flat rectangular prism.

$$\therefore \text{Volume} = \left\{\begin{matrix}\text{Base, or} \\ \text{Length} \times \text{Breadth}\end{matrix}\right\} \times \text{Height (or Thickness).}$$

$$\therefore \text{Thickness} = \frac{\text{Volume}}{\text{Base}}.$$

Find the area of the base by measurement, and the volume by rolling up the sheet and slipping it into a burette, taking care that no air bubbles remain under the water.

Check your result with a micrometer screw.

EXAMINATION PAPER ON VOLUME (Exp. 18-34)

1. What is meant by the area of a piece of paper? Has a piece of paper got volume? Give reasons for your answer.
2. Give formulæ for the volume of (1) sphere; (2) rectangular pyramid; (3) triangular prism; (4) cone; (5) cylinder. How would you prove that your formulæ were correct?
3. How many cubic centimetres are in (1) a litre; (2) a cubic kilometre; (3) a cubic hectometre; (4) a cubic millimetre?
4. Given the volume and length of a cylinder, how would you find the diameter? Find the diameter of a tube which holds 100 c.c. and is 5 cm. long.
5. A circular pond 300 metres in diameter is covered with ice 5 cm. thick. What is the shape and volume of the ice?
6. You are given a large sheet of paper, a straight-edge, and a burette. How would you find the thickness of the sheet of paper? State any method of testing your answer.

7. Two plums are apparently the same size. How would you find which contained the more pulp?

8. How would you find the volume of a grain of rice?

9. A box 20 cm. × 10 cm. × 5 cm. is filled with eggs, which are tightly packed in sawdust. Could you find how much sawdust is used?

10. In finding the capacity of a cylindrical beaker by getting how much water it holds a hole was accidentally knocked in the bottom. Suggest a method of finding the capacity.

11. How would you find the volume of a drop of water?

12. A rectangular swimming pond is 40 yards long, 35 yards broad, and 10 feet deep. The level of the water is 1 foot below the top of the pond. How much water is in the pond?

13. A flat ring ·2 cm. thick has an outside diameter of 5 cm., and an inside diameter of 1 cm. Find its volume.

CHAPTER IV

MASS AND RELATIVE DENSITY

RULES TO BE OBSERVED IN WEIGHING

1. PLACE yourself opposite the centre of the graduated scale.

2. Always use the forceps for lifting the weights, and do not touch them with the fingers or place them anywhere but in the box or on the pan.

3. Turn the handle to the right, and notice if the pointer swings an equal number of divisions on each side of the middle line on the graduated scale. If it does not, alter the nuts on the beam until it swings evenly. [Consult the teacher before doing this.]

4. Always have the beam lowered when you put a weight on or take it off.

5. Place the body to be weighed in the left pan and the weights in the right pan.

6. Weigh in the following manner:—Take a weight which you suppose is too heavy. Put it on the pan, raise the beam, using your left hand, and see if it is too heavy. If not, try a larger weight. If it is too heavy put it back in the box, and put on the weight next to it. See if this weight is too heavy. If so, replace it as before, and put on the next weight. If it is too light leave it in the pan, and put on the next weight. If the two weights are too heavy replace the last added weight, and add the weight next it.

Never pick out the weights at random. Work through the weights one by one until you find that the pointer swings an equal number of divisions on each side.

7. Arrange the weights in the pan, putting the largest in the centre, and the others in order round it.

8. Look in the box, and, beginning at the heaviest, make a list of the missing weights. Replace the weights which are on the pan in the box, beginning at the heaviest, and marking off each on the list when you replace it. When all the weights are removed from the pan, all the empty spaces in the box should be filled.

Suppose the weights taken from the box to be 50 gm., 10 gm., 2 gm., 2 gm., 500 mgm., 10 mgm., 1 mgm., the list would be:

gm.
50·
10·
2·
2·
·500
·010
·001
64·511

EXPERIMENT **35**

To find how many Square Centimetres are equal to one Square Inch

Apparatus—Paper, Scissors, Straight-edge.

Draw the plan of a box of weights. Remember that the unit of mass, 1 gramme (written 1 gm.), is the mass of 1 c.c. of pure cold water. Accustom yourself to the position of each weight in the box. Pick out weights at random (always using the forceps), and find the value of each by noticing which weights are missing from the box.

From the same sheet of paper cut a square inch and a square centimetre. Weigh each according to the rules for weighing.

Suppose the mass of the square inch of paper $= x$ gm., and the mass of the square centimetre of paper $= y$ gm.

Then if 1 sq. cm. of paper weighs y gm.,
How many „ „ „ x gm.?

Note.—Instead of cutting *one* sq. cm., and *one* sq. inch, which are rather small, it is better to cut a square of 2 cm. side and a square of 2 inches side.

Exercises

1. Find the area of a given figure (*e.g.* parallelogram, circle, etc.) by weighing the figure, then cutting a square centimetre out of the figure, and weighing it.

2. Weigh several needles (or pins) of different lengths, draw a graph, and use it to find the mass of a needle (or pin) of given length.

3. Find the number of grammes in a 1-oz. weight.

4. Cut any figure out of paper. Find its area by weighing. Check by squared paper.

5. Prove that the area of a circle $= \pi r^2$.

From the same sheet of paper cut a circle and four squares, the sides of which are equal to the radius of the circle. Place the circle in one pan and three squares in the other. Which is the heavier? Divide the fourth square into seven equal strips, and place one of these in the pan with the three squares.

6. Find the mass of a drop of water.

EXPERIMENT **36**

To find the Mass per Unit Volume of different Metals

Apparatus—Pieces of Metal in various Shapes (*e.g.* Cubes, Prisms, Pyramids, Cylinders, and Spheres).

Find the volume of each solid in two ways (1) by displacement; (2) by measurement.

Find its mass by the balance. [Mass is the amount of matter in a body, and is got by balancing the body against some pieces of metal (*i.e.* the weights) of which we know the mass.]

Arrange in a table.

Metal and Shape	Volume			Mass	Mass per c.c.
	Displacement	Measurement	Average		
Zinc (Cylinder) Bronze (Cube)					

The mass in a unit volume of any body is called the *Density* of that body. To distinguish it from another Density, about which we shall learn later, it is often called *Absolute Density*.

Absolute Density is the number of units of mass in a unit volume of the body—*e.g.* the Absolute Density of iron is about 7·2 gm. per c.c.

EXERCISES

1. You are given two rough pieces of metal, both gilt. One is gold, the other lead. How would you find which was the gold?

2. A sphere of copper is suspected to be hollow. How would you test?

3. Find the mass of a penny by finding its volume, and getting the mass per cubic centimetre of bronze from the table in Exp. 36.

EXPERIMENT **37**

To find the Absolute Density of Water

Apparatus—Burette, Beakers.

You have been told that the mass of 1 c.c. of water is 1 gm. Test if this is true.

Weigh 3 beakers. Into one put 50 c.c. of tap water, into the second 50 c.c of ice-cold pure water, and into the third 50 c.c. of hot water. Weigh, and get the mass of 1 c.c. of each kind of water. Is there any difference in the answers? Which answer is nearest 1 gm. per c.c.?

Remember that in future experiments the mass of water is to be taken as 1 gm. per c.c. unless otherwise stated.

Exercises

1. Find the capacity of a beaker by weighing the water it can hold.
2. A glass trough 50 cm. by 20 cm. by 15 cm. is half full of water. What is the mass of the water? If 3000 gm. of water are poured into the trough, what fraction of the trough is filled?
3. What will be the pressure of the water on the bottom of the trough when the trough is half full? What will be the pressure on 1 sq. cm. of the bottom?

EXPERIMENT **38**

To find the Relative Density of Solids

Apparatus—Stone, Apparatus of Exp. 21.

We say that iron is heavier than water. Does that mean that an iron ship is heavier than all the water in the sea on which it floats?

Iron is about seven times as heavy as water. This means that if equal volumes of iron and water be weighed, the iron will weigh seven times as much as the water.

Water is the standard substance with which we compare other bodies.

Relative Density[1] is the number of times that the mass of a body is as great as the mass of an equal volume of water.

Note that Relative Density is a *ratio* or *fraction* =

$$\frac{\text{Mass of Body}}{\text{Mass of equal Volume of Water}}.$$

Now the mass of 1 c.c. of water is the unit of mass (1 gm.)

$$\therefore \text{Relative Density} = \frac{\text{Mass of 1 c.c. of Body}}{\text{Mass of 1 c.c. of Water}}$$

$$= \frac{\text{Mass of 1 c.c. of Body}}{\text{1 gm.}}.$$

The mass of 1 c.c. of a body is called its *Absolute Density*, and is measured in gm. per c.c.

If the Absolute Density of iron is 7·2 gm. per c.c. what is its Relative Density?

Find the Relative Density of a stone in the following way:—

(1) Find its mass by the balance.

(2) Find its volume by displacement.

(3) Hence get its mass per c.c.

(4) Find the value of the fraction $\frac{\text{Mass of 1 c.c. of Stone}}{\text{Mass of 1 c.c. of Water.}}$

Find the Relative Density of various solids and write the answers in the tables at the end of the book.

EXERCISES

1. Find the Relative Density of sand by the same method. (See Exp. 24.)

2. Find the Relative Density of Wood.

---

[1] In some books the words *Specific Gravity* are used instead of *Relative Density*, though in a slightly different sense.

3. The Relative Density of a body is 2·43. Its volume is 31·3 c.c. What is the mass?

4. The Relative Density of salt is 2·22. What is the volume of a piece of rock salt, the mass of which is 100 gm.? How would you test if your answer were correct?

5. A block of stone in the shape of a prism is to be carted away. It is thought to be too heavy for the cart. How could the mass be got without moving the block?

6. The dimensions of the block in Ex. 5 are 6 ft. × 3 ft. × 2 ft. The density is 2·6. What is the mass?

7. A beaker is placed in one pan of a balance and shot is placed in the other till the beam swings evenly. In the latter pan a cube of metal (2 cm. side) is placed, and it is found that 45·4 c.c. of water have to be run into the beaker to balance this. What is the Relative Density of the metal?

EXPERIMENT **39**

To find the Relative Density of a Liquid

Apparatus—Pipette, Beaker, Alcohol.

Weigh a dry beaker. Into it place 50 c.c. of alcohol. Weigh, and so get the mass of the alcohol. What is the mass per c.c. of the alcohol? Arrange thus:

Mass of beaker = ... gm.
" " + Alcohol = ... gm.
∴ Mass of 50 c.c. of Alcohol = ... gm.

$$\text{Relative Density} = \frac{\text{Mass of 50 c.c. of Alcohol}}{\text{Mass of 50 c.c. of Water}} = \ldots\ldots$$

Here we take the mass of 50 c.c. of water to be 50 gm., but while the water is ice-cold the alcohol is at the temperature of the room. To be exact, we must find the mass of 50 c.c. of water, which is at the same temperature as the alcohol. To do this, weigh a dry beaker as before, place in it 50 c.c. of pure water which has been standing in the room, weigh, and so get the mass.

EXPERIMENT **40**

To find the Relative Density of a Liquid, using a Density Bottle

Apparatus—Density Bottle, Liquid (*e.g.* Alcohol).

Take a dry density bottle, weigh it with the stopper, and then fill it with the liquid. Insert the pierced stopper, wipe off any liquid which is on the outside, and weigh again.

Pour out the liquid, wash well with pure water, fill he bottle with pure water, and weigh. Arrange thus:

Mass of dry Bottle = 5 gm.
" " + Alcohol = 10 gm.
" " + Water = 12 gm.
∴ Mass of Alcohol = 5 gm. } equal
∴ " Water = 7 gm. } volumes.
∴ Relative Density of Alcohol = ...

Note.—Instead of a Density Bottle, a 1-oz. Stoppered Flask with a groove cut in the stopper may be used.

EXERCISES

1. It is suspected that some alcohol has had water added to it. How would you test?

2. A bottle which holds 20 c.c. is full of oil. The oil weighs 18·214 gm. The oil and some water are mixed, and allowed to stand. Which will settle to the bottom? Why?

3. The Relative Density of a liquid is 1·414. What is the volume of 50 gm. of the liquid?

4. A density bottle has no number marked on it. How could you find its capacity?

5. A density bottle holding 50 c.c. weighs, when filled with a liquid, 69·24 gm. The Relative Density of the liquid is 1·14. What is the mass of the bottle?

6. 20 c.c. of water are added to 40 c.c. of another liquid whose Relative Density is ·84. The volume of the mixture is found to be 57·8 c.c. What is the Relative Density of the mixture?

7. Find the Relative Density of sea water (or salt water).

EXPERIMENT **41**

To find the Relative Density of a Powder, using a Density Bottle

Apparatus—Density Bottle, Sand.

Weigh a dry, empty density bottle. Put some sand in it, so as to half fill it, and weigh.

Keep the sand in the bottle and pour water into it till it is filled. Tap the bottle to drive out any air which may be in it. When the bottle is full of water insert the stopper, wipe the outside, and weigh.

Lastly, empty the sand out, wash the bottle carefully, fill with water, and weigh. Arrange thus:

Mass of empty bottle = ... gm.
,, ,, + sand = ... gm.
∴ ,, sand = ... gm. I
,, bottle + sand + water = ... gm.
∴ ,, water (which is the bottle along with the sand) = ... gm.
∴ Volume of this water = ... c.c. II
Mass of bottle + water which fills it = ... gm.
∴ ,, water (which fills the bottle) = ... gm.
∴ Volume of water (which fills the bottle) = ... c.c. III
But volume of water which is with sand = (II) c.c.
∴ Volume of sand = (III-II) c.c.
∴ Mass of equal volume of water = (III-II) gm.

$$\therefore \text{Relative Density} = \frac{\text{Mass of sand}}{\text{Mass of equal volume of water}} = \frac{\text{(I) gm.}}{\text{(III-II) gm.}}$$

Exercises

1. Find the Relative Density of sugar (or salt), using a liquid (*e.g.* alcohol) in which it is insoluble.

2. If 20 c.c. of water are added to 5 c.c. of water, what is the new volume? Add 20 c.c. of water to 5 c.c. of sugar (or salt). [The Relative Density of sugar (or salt) is got from Ex. 1. Use this to get 5 c.c.] What is the new volume? Add water to sugar (or salt) in various proportions, and see if the new volume is exactly the sum of the volumes of the water and the solid. Can you state any reason why, in finding the Relative Density of a powder, you should not use a liquid which dissolves the powder?

EXPERIMENT **42**

The Principle of Archimedes

Apparatus—Thread, Stone, Beaker, Stool.

Take two pieces of thread the same length. Place one in the right pan of the balance, or suspend it from the hook above the right pan, and with the other suspend the stone from the hook above the left pan of the balance. The stone should hang 3 or 4 inches above the pan. Weigh the stone. (What about the mass of the thread?)

Place a stool across the left pan, and on it place a beaker nearly filled with water. Arrange the length of the thread so that the stone is always under the water, but not touching the beaker. Weigh the stone. Why is a smaller weight required? Arrange thus:

Weight in air = ... gm.
,, water = ... gm.
Apparent loss of weight = ... gm.

Now find the volume of the stone by displacement. Is there any connection between the weight of the water which is displaced by the stone and the apparent loss of weight found above?

(The water which is displaced tries to force the body upward, as if the water wanted to get back to its place again.)

Suppose you had used a basin of water instead of a beaker, would there be any difference in the loss of weight?

The fact that a body when weighed in water appears to lose weight equal to the weight of water displaced by the body was first discovered by Archimedes. The principle of Archimedes may be written thus:

"*When a body is weighed in air and then in water there is an apparent loss of weight equal to the weight of water displaced.*"

N.B.—In future we shall omit the word "apparent."

Suppose a body is weighed in air and in water.

Let weight in air = 10·251 gm.
and ,, water = 6·157 gm.

What is the loss of weight?

What is the weight of water displaced? What is the volume of water displaced? What is the volume of the body? Is this a good way of finding the volume of a body?

Repeat the experiment, using alcohol instead of water.

Is the principle of Archimedes true for all liquids?

Write a definition of the principle of Archimedes, so as to include all liquids.

EXERCISES

1. Find the volume of a small stone, using the principle of Archimedes.

2. Find the volume of a pin. [Tie several together and weigh.]

3. Tie weights on to a thread till the thread breaks. Tie the weights again to the thread, and suspend the weights in water. Does the thread break?

4. Explain why you can hold up a boy in water by placing your hand under his chin, when you cannot do this if the boy is not in water.

5. Does a boy displace more or less water when swimming in a bath than when swimming in a fresh-water lake?

6. Is there really a loss of weight in water?

7. Half fill a beaker with water, and weigh. Suspend a stone in the water, but not touching the beaker, by hanging it at the end of a thread which does not touch the balance. The other end of the string should be attached to a horizontal stick fixed into a clamp. Weigh the beaker and water. Is there any difference? Find the volume of the stone. Is there any relation between the answers?

EXPERIMENT **43**

To test if the Principle of Archimedes is true in the Case of a Body which floats in Water

Apparatus—Small piece of Wood, Thread, Beaker, Stool.

Fit up the apparatus as in last experiment, but instead of a stone suspend a small piece of wood.

Weigh the wood in air and in water. What peculiarity is there about the weight in water?

By the principle of Archimedes the difference of weight is equal to the weight of water displaced by the wood. Is the volume of this displaced water equal to the volume of the wood?

To find the volume of the water displaced pour some water into a graduated jar, and note the reading. Slip the wood into the water so that it floats, and note the volume of the water displaced. Is the principle of Archimedes true?

Now push the wood under the water, and get its volume. Which of the two answers is the greater?

EXERCISES

1. Why has a piece of wood no apparent weight in water? A piece of wood is suspended by a thread from a spring balance. The wood is lowered into water. What is the pull on the thread?
2. A piece of wood displaces 20 c.c. of water when it floats. What is the weight of the wood in air? [The wood has no weight in water, so the weight in air is equal to the weight of water displaced—*i.e.* 20 gm.]
3. From Ex. 2 find a method of getting the weight of a piece of wood without weighing the wood.
4. Why does a piece of wood float in water? Which weighs the more—equal volumes of wood or water? Within what limits must be the Relative Density of a body which floats?

EXPERIMENT **44**

To find the Relative Density of various Solids by the Principle of Archimedes

Apparatus—Various Solids (*e.g.* Metals), Thread, Stool.

Find the weight in air and in water, and so get the loss of weight.

Then Relative Density =

$$\frac{\text{Mass of Body}}{\text{Mass of equal volume of Water}} = \frac{\text{Weight of Body}}{\text{Loss of Weight}}.$$

Arrange in a table.

Solid	Weight in Air	Weight in Water	Loss of Weight	Relative Density

Is this method a good one? Is it preferable to the method of Exp. 38? Why?

EXERCISES

1. Draw a graph of the results of the last experiment, marking the metals along the horizontal axis at distances of 1 cm., and the Relative Density by vertical lines.
2. A brass pin is weighed. The Relative Density of brass is in your table. Find the volume of the pin. Is this a good method of finding volume?
3. A ship is fully laden at a river port so that a line on the ship is at the level of the water. As the ship proceeds down the river to the sea, how will the line move relatively to the surface of the water?
4. A long rod floats vertically in water. It is pushed down, and then let go. Why does it come up again?
5. Find the Relative Density of a weighing bottle or a bottle with a glass stopper (1) open; (2) shut. Why is the answer in the second case less than in the first case?

EXPERIMENT **45**

To find the Relative Density of a Body which floats in Water

Apparatus—Piece of Wood, Sinker of Lead or a Glass Stopper.

Weigh the wood in air.

The problem now is to find the weight of the wood in water. This is got by finding (1) the weight of the sinker in water; (2) the weight of the sinker + wood in water.

Weigh the sinker in water. I.

Tie the wood and sinker together, and weigh in water. II.

Subtract I. from II.

∴ Weight of wood in water = …… gm.

What peculiarity do you notice about the weight of the wood in water? Can you explain it?

You have now the weight in air and in water.

∴ Loss in weight of wood = …… gm.

$$\therefore \text{Relative Density of wood} = \frac{\text{Weight in Air}}{\text{Loss of Weight}} = \ldots\ldots$$

Example—

Weight of body in air = 1·44 gm.
Weight of sinker in water = 8·87 gm. I
Weight of (sinker + body) in water = 3·22 gm. II
∴ Weight of body in water = II − I = − 5·65 gm.
But weight of body in air = 1·44 gm.
∴ Loss of weight = 1·44 − (− 5·65) gm. = 7·09 gm.

$$\therefore \text{Relative Density of body} = \frac{1\cdot44 \text{ gm.}}{7\cdot09 \text{ gm.}} = \ldots\ldots$$

EXPERIMENT 46

To find the Relative Density of Liquids by Archimedes' Principle

Apparatus—Beakers containing Water and various Liquids, Stone.

Hang the stone to the balance as in previous experiments, and weigh the stone in air and in water.

Replace the beaker of water by one of the liquids, dry the stone carefully, let it hang in the liquid, and weigh it while hanging in the liquid.

Arrange as follows :—

Weight of stone in air = ... gm.
" " water = ... gm.
∴ Loss of weight in water = .20. gm. I
Weight of stone in air = ... gm.
" " liquid = ... gm.
∴ Loss of weight in liquid = .18. gm. II

Answer I is equal to the mass of a certain volume of water. (What volume?) Answer II is equal to the mass of a certain volume of liquid. Are the two volumes equal?

Then, Relative Density = $\dfrac{\text{Mass of Liquid} \quad 18}{\text{Mass of equal volume of Water}}$ =

$\dfrac{\text{Loss of weight of stone in Liquid}}{\text{Loss of weight of stone in Water}}$ = ...

EXERCISES

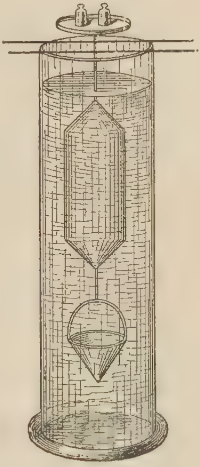
1. A stone weighs 10 gm. in air and 7·4 gm. in water. What will it weigh in alcohol, whose Relative Density is ·83?

2. A stone whose volume is 10·3 c.c. weighs 23·5 gm. in air and 12·4 gm. in a liquid. What is the Relative Density of the liquid?

EXPERIMENT **47**

To find the Relative Density of a Solid, using Nicholson's Hydrometer

Apparatus—Nicholson's Hydrometer; Glass Jar (at least 1 inch longer than the Hydrometer, and wide enough to admit it easily); two Pencils or Straight-edges or Wires to lay across the top of the Jar, to prevent the pan of the Hydrometer sinking under the Water; Stone or other Solid.



Place the hydrometer in the jar, which should be nearly full of water. Add weights to the upper pan till a mark on the stem of the hydrometer is at the water-level.

Remove the weights, place the solid in the upper pan, and add weights till the hydrometer sinks again to the mark.

Weights to sink to mark = ... gm.
Solid in top pan + weights to mark = ... gm.
∴ Weight of solid in air = ... gm.

Now place the solid in the bottom pan which is under the water, and add weights, as before, to the top pan to sink to the mark.

Weights (alone) to sink to mark = ... gm.
Solid in water + weights to sink to mark = ... gm.
∴ Weight of solid in water = ... gm.

Now use Archimedes' Principle to find the Relative Density of the solid.

Note.—When the solid will not remain under water, as in the case of wood or cork, tie it to the bottom pan with a small piece of thread, or squeeze it into the pan so that it cannot escape.

EXERCISES

1. Explain the reason of the method you have employed in this experiment to get the weight of the solid.
2. A solid weighs 16 gm. when placed in the top pan and 12·25 gm. when placed in the bottom pan. Find its volume.
3. Find the Relative Density of wood by Nicholson's Hydrometer. What peculiarity do you notice about the weights required to sink to the mark in air and in water? Can you explain? (See Exp. 45.)

EXPERIMENT **48**

To find the Relative Density of a Liquid by Nicholson's Hydrometer

Apparatus—Same as Exp. 47.

Perform Exp. 47 again. After you have done it take the hydrometer out of the water, dry it, and place it in a jar full of the liquid. Repeat with the liquid what you did with the water. Arrange in a table.

WATER	LIQUID
Weights to sink to mark = ...gm.	Weights to sink to mark = ...gm.
Stone in air + wts. to sink = ...gm.	Stone in air + wts. to sink = ...gm.
∴ Weight of stone in air = ...gm.	∴ Weight of stone in air = ...gm.
I	IV
Stone in water + wts. to sink = ...gm.	Stone in liquid + wts. to sink = ...gm.
∴ Weight of stone in water = ...gm.	∴ Weight of stone in liquid = ...gm.
II	V
∴ Loss of weight in water = ...gm.	∴ Loss of weight in liquid = ...gm.
III	VI

What weights do we find from III and VI? What are the volumes of the water and the liquid displaced? Why are they equal?

Having found the weights of equal volumes of water and the liquid, find the relative density as before. What do you notice about answers I and IV?

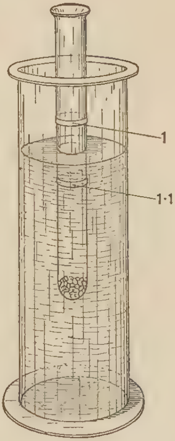
EXPERIMENT **49**

To construct a Common Hydrometer

Apparatus—Long narrow Test-tubes, Shot, Jars of Liquids.

Take a jar of water, and float a test-tube in it, adding shot to the tube till it floats upright. Mark the tube at the level of the water with a strip of paper, and put "1" on the paper.

Take jars of other liquids whose Relative Density you have found, and place the test-tube in each. If you see the tube is going to sink or not float upright, place the liquid aside, and prepare other test-tubes for these liquids. If the tube floats upright, mark the tube at the level of the liquid. When you have marked all the tubes you will have a set of Common Hydrometers.



Take a liquid whose Relative Density is unknown. Find one of the tubes which floats upright in it. Take note of the reading at the surface of the water. If the level of the water is between two strips on the tube, find the reading by proportion. Test your answer by using the Common Hydrometers supplied to you.

Another hydrometer which is sometimes used is Twaddell's Hydrometer. Here the reading is multiplied by five, the answer added to 1000, and this result divided by 1000.

Suppose the reading is 35.

$$\text{Then Relative Density} = \frac{(35 \times 5) + 1000}{1000} = 1{\cdot}175.$$

Twaddell's Hydrometer can be used only for liquids which are heavier than water.

EXPERIMENT **50**

To find why some Bodies float in Water

Apparatus—Graduated Jar, Wood, Test-tube, Glass Stopper.

Weigh a piece of wood. Place it in a measuring jar, and note how much water is displaced. What is the mass of the water displaced? Compare the mass of the wood and the mass of the water displaced. Why would you expect them to be equal? What about the volume of the wood and the volume of the displaced water? Which is greater? If equal volumes of the water and the wood were taken, which would weigh the more? Which has the greater density?

Weigh a glass stopper. Find the volume of water it displaces. What is the mass of the displaced water? Which is greater, the mass of the stopper or the mass of the displaced water? When does a body sink in water?

Weigh a glass test-tube. Place it mouth upwards in a graduated jar. Does it sink? How much water is displaced? What is the mass of the displaced water?

You will see that the glass stopper sinks and the glass test-tube floats. In the first case the mass of the glass is greater than the mass of the displaced water; in the second case the mass of the glass is equal to the mass of the displaced water. If, then, we want a body to float we must get it to displace as much water as will equal the body in mass. This is got by increasing the outside volume of the body by making the body hollow. For example, a sheet of metal will sink in water. If, now, the sheet is bent up round the edges, so as to form a kind of saucer, it will probably float.

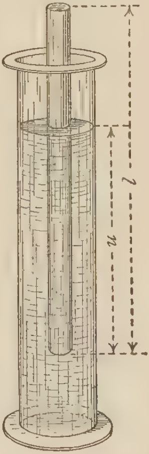
Can you explain now why a Nicholson's Hydrometer floats in water, though it is made of metal? Why are weights required to sink it farther? When these weights are removed, why does the hydrometer rise farther out of the water?

EXPERIMENT **51**

To find the Relative Density of a Rod of Wood by Flotation

Apparatus—Rod of Wood with a constant Cross-Sectional Area (*i.e.* if the Rod is cut at any point, parallel to the Base, the Area is always the same), Cylindrical Jar.

Fill the jar full of water. Place the rod in the jar so that it floats vertically. Measure the length of the rod under water and the total length of the rod.



$$\text{Then Relative Density} = \frac{\text{Length under Water}}{\text{Total Length}}.$$

Proof:

Let the area of the cross-section = A sq. cm.
„ length of rod = l cm.
„ length under water = u cm.
„ Relative Density of the rod = d.
The volume of rod = $A \times l$ c.c.
Volume of rod under water
= Volume of water displaced = $A \times u$ c.c.

The mass of the rod = $A \times l \times d$ gm. (Why?)
The mass of the water displaced = $A \times u$ gm.

The rod presses downward, while the displaced water presses upward, and as the rod remains steady the two pressures are equal; but the pressures are caused by the masses.

$$\therefore\ A \times l \times d \text{ gm.} = A \times u \text{ gm.}$$

$$\therefore\quad d = \frac{A \times u}{A \times l} = \frac{u}{l}$$

$$\therefore \text{ Relative Density} = \frac{\text{Length under Water}}{\text{Whole Length}}.$$

Where the wood has not a regular shape the density is found by measuring (1) the water displaced; (2) the total volume of the wood. (See Exp. 43, Ex. 2.)

EXPERIMENT **52**

To find the Relative Density of Liquids by a Rod

Apparatus—Jars of different Liquids, Rod used in Exp. 51.

Measure the length of the rod. (Suppose it is l cm.) Call the area of the end of the rod A sq. cm. What is the volume of the rod?

Float the rod in a liquid. Measure the length of the rod under the liquid. (Suppose it is t cm.) What is the volume of the liquid displaced?

Before you can find the relative density of the liquid you must get the mass of the liquid displaced. This is equal to the mass of the rod. (Why?)

To find the mass of the rod place it in a jar of water. Measure the length under water. (Suppose it is u cm.) What is the mass of the water displaced? Can you now find the mass of the liquid displaced?

From the volume and mass of the liquid displaced find the Relative Density.

Compare the length of the rod under water, the length under the liquid, and the Relative Density. From these could you write down the rule for finding Relative Density?

Proof of rule :

Volume of liquid displaced $= A \times t$ c.c.
Volume of water displaced $= A \times u$ c.c.

Suppose the Relative Density of the liquid $= d$.

$\therefore$ Mass of liquid displaced $= A \times t \times d$ gm.
and Mass of water displaced $= A \times u$ gm.

These two masses are equal because each is equal to the mass of the rod. (Why?)

$$\therefore\ A \times t \times d = A \times u$$

$$\therefore\ d = \frac{A \times u}{A \times t} = \frac{u}{t} = \frac{\text{Length of Rod under Water}}{\text{Length of Rod under Liquid}}.$$

EXPERIMENT **53**

To find the Diameter of a Capillary Tube

Apparatus—Capillary Tube 4 or 5 inches long, Mercury.

Weigh the capillary tube. Dip one end under mercury (at least 1 inch), place your finger on the other end, and lift the tube out. If there is no mercury in the tube try this method: Dip the end under the mercury, and suck some mercury up the tube, taking care that no water gets into the tube. What is the shape of the column of mercury?

Lay the tube on a sheet of white paper, and measure the length of the column of mercury. By tilting or tapping the tube move the mercury to another part of the tube. Measure the length of the column. Do this at different parts of the tube. If the length of the column is not always the same, what can you tell about the diameter of the tube?

Measure the length in a certain part of the tube, wipe the tube carefully to get rid of any moisture, and weigh the tube with the mercury. Hence find the mass of the mercury.

From your tables get the Relative Density of mercury. Use this to find the volume of the column of mercury. You have the volume and the length of a cylinder of mercury. From these find the diameter. (See Exp. 32.) Arrange in a table.

Mass of tube = ... gm.
Mass of tube + mercury = ... gm.
∴ Mass of mercury = ... gm.
Relative Density of mercury = ...
∴ Volume of Mercury = ... cc.
Length of column = ... cm.
∴ Area of end of column = ... sq. cm.
∴ Diameter = ... cm.

Exercise

Find the diameter of a piece of glass tube by fitting corks into the ends and finding the mass of the water it can hold.

EXAMINATION PAPER ON WEIGHING AND RELATIVE DENSITY (Exp. 35-53)

1. What is meant by saying that iron is heavier than water? How many times is iron as heavy as water? If you do not know, how would you proceed to find out?
2. An irregular figure with curved sides is cut from a sheet of paper. Describe two methods of finding its area.
3. What is a litre? If a litre flask is filled with pure cold water, what is the mass of the water? If hot water is used, is there any difference?
4. Define: Absolute Density, Relative Density, Mass, Weight. The Relative Density of Brass is 8·4, what is the Absolute Density?
5. State the principle of Archimedes. How would you find the volume of a stone by this principle?
6. A liquid has the same taste, colour, and appearance as pure water. State any method of finding if it is water.

7. A dairyman is suspected of having watered his milk. How would you prove if the suspicion is correct?

8. Why does an empty tin can float in water?

9. Nickel and platinum have the same appearance. A crucible (or cup) is made of one of these metals. How would you find which metal it was?

10. If 109 cubic inches of milk weigh 4 lbs., and 1 cubic foot of water weighs 1000 ounces, what is the Relative Density of milk?

11. How would you find the mass of a piece of wood, using only a graduated jar?

12. How would you find the Relative Density of a rod by flotation? Would a cut pencil or a penholder do? Give reasons.

CHAPTER V

PRESSURE OF AIR, ETC.

EXPERIMENT **54**

To show that Air presses in all Directions

1. To show that air presses downward.

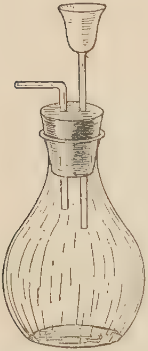
Apparatus—Beaker.

Take a beaker, and push it, mouth downwards, into a basin of water. Why does the water not rise as far inside the beaker as outside?

2. To show that air presses upward.

Apparatus—Pipette, Flask, Rubber Cork, Glass Tubing.

Suck some water into a pipette, and keep your finger on the top. The bottom of the pipette is open. There are two things touching the water, the glass of the pipette and the air. Which is keeping the water up? Take your finger away from the top. Why does the water run out?



Take a rubber cork with two holes, and fit it in a flask. Through one hole place a tube bent at right angles and through the other a thistle funnel. Close the end of the bent tube with your finger. Pour some water into the funnel. Describe and explain what happens.

3. To show that air presses in all directions.

Apparatus—Toy Balloon, Thread, Air Pump.

Take an ordinary toy balloon, and blow into it. What shape does it generally assume? In what directions does the air exert a pressure? Half fill the balloon, tie the mouth tightly, place it under the receiver of an air pump, and exhaust. What happens? Explain.

Does air press equally in all directions?

EXERCISES

1. Explain the action of a boy's sucker. Can a sucker stick on a wall or a roof?

2. If a penny is pressed and rubbed against a smooth wall it often sticks to the wall. Why?

3. Examine the rubber cones used by shopkeepers for fixing cards to the windows. Explain their action.

4. Press together two cover glasses of a microscope slide. Try to separate them.

5. A tumbler is filled with water so that the water overflows. A piece of stout paper is pressed against the rim of the tumbler, the tumbler inverted, and the hand holding up the paper withdrawn. What happens? Would the result be the same if the tumbler were not completely filled with water?

6. Stretch a piece of thin rubber sheet over the top of a bottomless ground-glass cylinder, and tie it so as to make air-tight. Grease the other end, and place on the plate of an air pump. Exhaust the air. What happens?

7. Exhaust the air from a pair of Magdeburg hemispheres. What does this experiment teach you about the directions in which air presses?

EXPERIMENT **55**

To get some Notion of what Pressure is

Apparatus—Mercury, long Tubes of various Bores, Flask with Rubber Cork, U Tube, Rubber Tubing, Clip.

Take a long, narrow glass tube, put one end into a beaker full of mercury, and suck the air out of the tube with your mouth. What happens? Take a note of the height the mercury rises in the tube. You will find some difficulty in keeping the mercury standing in the tube, but with practice you should manage it. (If a piece of rubber tubing with a clip on it is stretched over the end of the glass tube the difficulty is avoided.) Do the same with tubes of different bores, and measure the height of the mercury in each case. You should get the answers nearly the same. What made the mercury rise in the tubes?

To test if it is the pressure of the air on the mercury in the beaker that forces the mercury up the tube, take a flask, and insert in it a stopper with two holes, through which are two glass tubes. In the flask place some mercury, and allow one of the tubes to dip under it. Suck the other end of this tube. What happens? Place a piece of rubber tube with clip over the tube which does not dip in mercury. Open the clip, suck the air out and close. Now suck the tube which dips under the mercury. Does the mercury rise? Can you explain the difference?

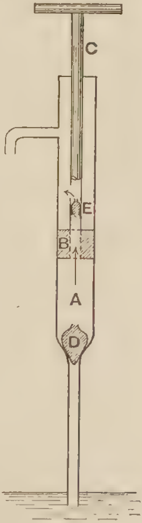
Take a U tube, and pour a little mercury into it. Mark the levels of the mercury. Are the levels the same in both tubes? What is pressing on the mercury in the two tubes? If the pressure on the mercury in one tube is greater than the pressure in the other tube, would you expect the levels to be the same?

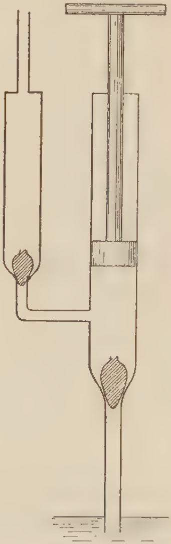
Now make a U tube in which one of the tubes is wider than the other. This is done by connecting two straight tubes (one being wider than the other) by a piece of rubber tubing. See that the rubber tubing fits tightly over the glass tubes. Pour mercury into the U tube. Are the levels the same? Is the pressure the same in both tubes? But one tube is wider than the other, so that the surface of mercury pressed on by the air is greater in the wide tube. Will the total pressure on the mercury in the wide tube be equal to the total pressure on the mercury in the narrow tube? Yet we said that the pressure was the same in both tubes. Do we mean *total pressure* when we say the *pressure* is the same in both tubes? What do we mean?

EXPERIMENT **56**

To explain the Action of Suction and Force Pumps

Apparatus—Glass Models of the Suction Pump and the Force Pump.





Examine the suction pump. A is called the cylinder or barrel or chamber, B the piston, C the piston rod. D is a valve at the foot of the cylinder which can move upward but not downward. Notice that the piston rod is hollow as it passes through the piston and that there is a valve E similar to D. Also there is a hole in the piston rod, so that there is communication between the upper and lower parts of the cylinder.

Push the piston down as far as possible. What do you notice about D and E? Place the end of the tube which leads to the cylinder under water, and pull up the piston. What happens? Can you explain? Push down the piston. Explain the action.

Examine the force pump. Is the piston rod hollow? Notice that there are two cylinders. Notice the action of the two valves. Work the pump, and explain the action.

EXERCISE

On which principle would you expect a fire-engine pump to be constructed?

EXPERIMENT 57

To find the Relative Density of a Liquid, using a U Tube

Apparatus—U Tube on Stand.

Pour a little mercury into a U tube, and mark the levels with a rubber ring or gummed paper. Into one tube pour some water. Are the levels of the mercury the same? Why not? What is pressing on the mercury in each tube?

Pour some of the liquid down the other tube, a little at a time. What about the difference between the levels of the mercury? Pour enough liquid into the tube to make the surfaces of the mercury level as at the beginning. What now is pressing on the surfaces of the mercury? If the level of the surfaces of the mercury is the same, what about the pressure on each surface?

∴ Pressure of Air + Pressure of Water = Pressure of Air + Pressure of Liquid.

∴ Pressure of Water = Pressure of Liquid.

Measure the height of the columns of water and the liquid.
Suppose the area of the tube to be A sq. cm.
Suppose the height of water column = a cm.
Suppose the height of liquid column = b cm.

∴ Volume of water column $= A \times a$ c.c.
Mass of water column $= A \times a$ gm.
Volume of column of liquid $= A \times b$ c.c.

Since the masses of the columns are equal (for the pressures are equal), we have $A \times b$ c.c. of liquid weighing $A \times a$ gm.

∴ b c.c. of liquid weigh a gm.

∴ 1 c.c. of liquid weighs $\frac{a}{b}$ gm.

$$\because \text{Relative Density of liquid} = \frac{\frac{a}{b}\text{gm.}}{1\text{ gm.}} = \frac{a}{b}$$

$$\therefore \text{Relative Density of liquid} = \frac{\text{Height of Water Column}}{\text{Height of Liquid Column}}.$$

If the two tubes were not of the same width, would there be any difference in the result?

Note.—An easy way of finding the height of the columns is to gum strips of squared millimetre paper on the stand behind the tube. Number the centimetres, beginning at the bottom.

EXPERIMENT **58**

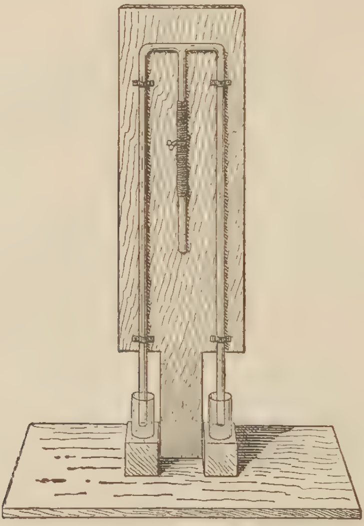
To find the Relative Density of a Liquid, using Hare's Apparatus

Apparatus—Hare's Apparatus, with Strips of Squared Paper behind the Tubes.

Place some water in the two beakers, loosen the clip on the rubber tube, and suck till the water is more than half way up the tubes. Close the clip, measure the height of the water columns—that is, the distance between the surface of the water in the beaker and in the tube. Are the heights the same? Would you expect this? Give your reasons. Open the clip. Why does the water fall back to the beakers?

Pour the water out of one of the beakers, and place some of the liquid in the beaker. Replace the beaker under the tube, and suck as before. Measure the height of the two columns.

Let the height of the water column $= a$ cm.
and the height of the liquid column $= b$ cm.
Let the area of the tube $= A$ sq. cm.
$\therefore$ Volume of water column $= A \times a$ c.c.
" liquid column $= A \times b$ c.c.



What is keeping up the columns?

On the top of the columns the air in the tube is pressing down, but this pressure is less than the pressure of the air outside. Why?

Then Pressure of Air outside = Pressure of Water Column + Pressure of Air inside.

Also Pressure of Air outside = Pressure of Liquid Column + Pressure of Air inside.

$\therefore$ Pressure of Water Column = Pressure of Liquid Column. (Why?),

but Pressure of Water Column = $A \times a$ gm.

$\therefore$ $A \times b$ c.c. of liquid weigh $A \times a$ gm.

$\therefore$ b c.c. of liquid weigh a gm.

$\therefore$ 1 c.c. of liquid weighs $\frac{a}{b}$ gm.

$$\because \text{ Relative Density of liquid} = \frac{\frac{a}{b}\text{ gm.}}{1\text{ gm.}} = \frac{a}{b}$$

$$\therefore \text{ Relative Density} = \frac{\text{Height of Water Column}}{\text{Height of Liquid Column}}.$$

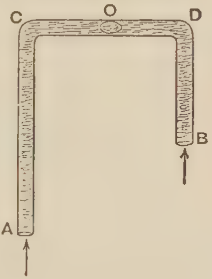
Would there be any difference if the tubes were not the same diameter? Yes a great deal.

EXPERIMENT 59

The Syphon

Apparatus—Syphon Tube, two Beakers.

Suppose the syphon tube is full of water, and that in the centre of the horizontal part there is a particle of water O. We wish to find in which direction (if any) O will move.



In the long arm there are two pressures—the pressure of the air upward and the pressure of the column of water downward. Therefore urging O towards the right there is a pressure = pressure of air − pressure of column of water AC.

Similarly urging O towards the left there is a pressure = pressure of air − pressure of column of water BD. Which of the two pressures is the greater? In which direction will the water move?

Fit the syphon on to a jar (see Exp. 21), with the shorter end in the jar. Fill the jar with water. Commence the action by sucking at A to fill the tube. When does the action stop?

Can you explain the action of the syphon in Exp. 21 when the longer tube is in the jar?

EXERCISES

1. A syphon is made of rubber tubing. By accident a small hole is made in the top of the tube while the syphon is working. What will happen? Try the experiment.

2. A syphon in working order is placed under the receiver of an air pump. The air is exhausted. Will the syphon stop acting?

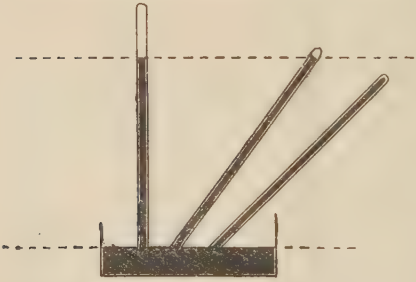
EXPERIMENT **60**

The Barometer

[If thought advisable, the teacher may perform this experiment.]

Apparatus—Straight Tubes about a metre in length and closed at one end, Mercury, small Trough or Basin, bent Barometer Tubes.

Measure the diameter of a straight tube in inches and in centimetres, and find the area of the open end.



Fill the tube with mercury, place your thumb tightly on the end, and invert into a trough of mercury. Take your thumb away. What happens?

Measure the height of the column of mercury in inches and in centimetres. Ask your neighbour the diameter of his tube and the height of the column. Does the difference of diameter make a difference in height?

Slope the mercury tube till the mercury is nearly at the top.

Measure the perpendicular height of the column. Is there any difference from the first reading? Slope the tube still more. What happens? Can there be any air at the top of the tube? Does the mercury make any noise when it strikes against the top of the tube?

Fill the bent tube given you. [It consists of two tubes, one (1 foot long) open at both ends, the other (3 feet long) closed at one end. Connect an open end of each by a short piece of thick rubber tubing.] To fill the tube, hold it vertical, pour in mercury to the top, and place your finger on the top. Invert the tube, bend it at the rubber, hold it over a trough and remove your finger. Does the mercury run out at the open end? Measure the height of the mercury between the levels in the two tubes. Blow down the open tube. What happens? Suck some air out of the open tube. What happens?

Can you now give the reason why the mercury remains in the tube? What is the mass of the mercury in the long tube? (Density of mercury = 13·6, and mass of 1 cubic foot of water = 62·5 lb.) What would be the mass of the column of mercury if the area of the tube were (1) 1 sq. cm. (2) 1 sq. inch? With what force does the air press on bodies?

Why is it that we do not feel this pressure?

Exercises

1. Explain why the diameter of the tube has no effect on the height of the barometer.

2. Could we use water instead of mercury? What would be the height of a water barometer? Mention any advantages and disadvantages of a water barometer. Would a glycerine barometer have the same disadvantages as a water barometer?

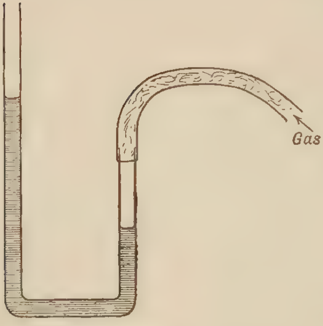
3. What would happen if a hole were knocked in the top of a barometer tube?

4. It is found that as you ascend up mountains the height of the barometer becomes proportionally less. How could you find the height of a mountain? [An aneroid barometer is used because of its handy size.]

5. A barometer is sometimes called a "weather glass."

Explain the connection, if any, between the barometer and the weather.

6. What is the greatest depth from which a suction pump can lift water? Could a suction pump lift water from a mine?



7. What is the greatest height through which a syphon can work?

8. Measure the pressure of the gas in the laboratory by attaching the rubber tubing of a bunsen burner to one end of a glass tube with a double bend. Into the glass tube pour some water. Turn on the gas slowly, and note what happens. If the water rises too high in the open tube add some more water. Measure the difference in levels, and so find the mass of water and the pressure of the gas per square inch.

9. Above the mercury in the trough, in which the barometer tube is standing, pour some water to form a layer at least 6 inches deep. Raise the tube gradually till the lower end just rises above the mercury in the trough. What happens (1) to the mercury in the tube; (2) to the water in the trough? Can there be anything in the space above the mercury in a barometer tube?

10. Read the school barometer daily, and draw a graph.

EXPERIMENT **61**

Boyle's Law

First Method

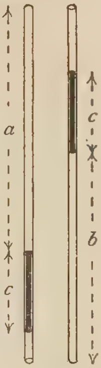
Apparatus—Piece of Glass Tubing of Bore not greater than $\frac{1}{16}$ inch and about 2 feet long, Mercury.

If you have two tubes of the same bore, one of them being twice the length of the other, how would the volume of the one compare with the volume of the other? When can we compare volumes by comparing lengths? Suppose that in one of these tubes there is a column of mercury, and in the other tube a column of mercury which is half the length of the first. Compare the weights or pressures of the columns of mercury.

Take the glass tubing provided, and heat one end in a bunsen burner flame till there is a very small opening left. Cool, and place the other end under mercury. Suck till the mercury fills about a quarter of the tube. Place your finger over the end of the tube which is under the mercury, lift the tube out, and heat the other end till it is sealed.

Allow to cool, place the tube over the trough of mercury in a vertical position, with the open end downwards, and take away your finger. Why does the mercury not fall out? You have now a column of air enclosed by a column of mercury. Measure the length of the columns.

Place your finger on the open end, and invert the tube so that the column of air is at the bottom. Measure the lengths of the columns. Is there any difference? Take the reading of the barometer (say t cm.). Let the length of the air columns be a and b cm. respectively and the length of the mercury column c cm. Then the first volume is represented by a cm., and the pressure on it is represented by the pressure of the atmosphere minus the pressure of c cm. of mercury. What is the volume in the second case? Is the pressure the same?



	Volume	Pressure	Volume × Pressure
First	a	$t-c$	$a\,(t-c)$
Second	b	$t+c$	$b\,(t+c)$

Compare the answers in the last column. Are they the same? Repeat with the tube horizontal. What is the pressure of the column of mercury? Hold the tube sloping with the open end over the mercury trough, and tap gently. A little mercury falls out. Repeat the experiment as before.

Boyle's Law states that the product of the pressure and the volume of a gas contained in any vessel is constant.

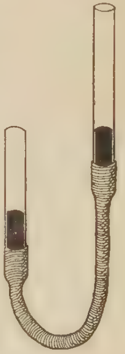
If V_1, P_1; V_2, P_2; V_3, P_3, etc., be corresponding volumes and pressures, then

$$V_1 P_1 = V_2 P_2 = V_3 P_3, \text{ etc.}$$

From this it is seen that if the pressure is doubled the volume becomes one half; if the volume is increased three times the pressure becomes $\frac{1}{3}$, etc.—in other words, the volume varies inversely as the pressure. $V \propto \frac{1}{P}$.

Second Method

Apparatus—Two pieces of Barometer Tube, Rubber Tube (1 yard long) to fit same.



Take two pieces of wide glass tubing about 18 inches long. Seal an end of one of them in a blowpipe flame. Connect the open ends of each by a piece of rubber tube, which should be bound with wire or string.

Fix the closed tube vertically in a clamp. Pour mercury down the open tube till the mercury appears above the rubber tubing when the two glass tubes are about the same level. Fix the open tube vertically in a clamp which can be raised or lowered.

Measure the length of the air column in the closed tube and also the difference between the levels of the mercury. What is pressing on the air in the closed tube? Now raise the open tube. What happens? Measure the new volume and the new pressure. Repeat this several times, and arrange in columns.

Volume	Pressure	Volume × Pressure

If there are ordinary "Boyle's Law Tubes" in the laboratory they may be used instead of the two pieces of glass tube.

EXERCISES

1. On the top of a 1-inch pump piston a 10-lb. weight is placed. The volume of the air in the pump is 20 c. inches. What will be the volume when a 20-lb. weight is placed on the piston? (Pressure of atmosphere = 15 lb. per sq. inch.)
2. How can the pressure of the atmosphere be found by the apparatus of the First Method if Boyle's Law is taken as proved?
3. Draw a graph of the pressures and volumes found above.

EXPERIMENT **62**

To find the Relative Density of Gases

Apparatus—Air Pump, round-bottomed Flask having Rubber Cork with one Hole, through which is a short Glass Tube, with Rubber Tube and Clip attached.

When finding the densities of gases we do not use water as the standard of comparison, but air. Weigh the flask. Attach the rubber tube to an air pump, open the clip, and exhaust the flask. Weigh the flask when empty. What will the difference of the weighings give you?

Now fill the flask with a gas (*e.g.* coal gas). To do this take out the cork (open the clip), and lead a tube from the gas pipe to the bottom of the flask. Turn on the gas, and let a brisk stream of gas pass through the flask, which should be inverted. Insert the cork, shut the clip, and weigh. Arrange thus:

Mass of flask, etc. + air = ... gm.
Mass of flask, etc. = ... gm.
$\therefore$ Mass of air = ... gm.
Mass of flask, etc. + gas = ... gm.
$\therefore$ Mass of gas = ... gm.

But the volumes are equal, therefore we can find the Relative Density of coal gas compared with air.

Find the volume of the flask from the volume of water it holds, and so get the mass of a litre of air.

Exercise

Why does a balloon filled with coal gas or with hydrogen float in air?

EXAMINATION PAPER ON PRESSURE (Exp. 54-62)

1. A few drops of water are introduced into a barometer tube. Explain what happens.
2. The occupants of a balloon which is very high in the air often have bleeding at the nose and ears. Can you account for this?
3. What will be the normal height of a water barometer? Show how you calculate it. The water in a well is 60 feet from the surface. What kind of pump will you require to pump it up? Give your reasons.
4. A balloon of 3000 c.c. capacity is filled with air at the ordinary atmospheric pressure (760 mm.). The mouth is tied, and it is placed under the receiver of an air pump till the

pressure is 300 mm. What will be the volume of the air in the balloon (neglecting the resistance of the balloon to stretching)?

5. The area of a man's head is 1200 sq. cm. What is the total pressure of the air on his head? Why is the great pressure of the air not perceived by the man?

6. The Cartesian diver is a hollow glass man with a small hole in one of the feet.[1] It is placed so as to float head upwards in a jar half full of water. The jar is made air-tight by stretching a sheet of indiarubber over the top. On pressing the rubber down the diver sinks a little, and on relieving the pressure rises again. Can you explain this?

7. Explain the principle of the air pump or of the aneroid barometer.

8. A flask of 1 litre capacity weighs 24·375 gm. empty, 25·607 gm. when full of air, and 27·164 gm. when filled with another gas. Find the mass of 1 c.c. of air and the Relative Density of the gas.

9. How is the Relative Density of a liquid found (1) by a **U** tube; (2) by Hare's Apparatus? In a **U** tube a column of liquid 10 cm. in length is balanced by a column of water 12 cm. in length. The diameter of the tube in which the liquid is, is double the diameter of the other tube. Find the Relative Density of the liquid.

10. The mass of 1 c.c. of air is ·00125 gm. and the mass of 1 c.c. of mercury is 13·596 gm. A column of mercury 760 mm. high is balanced by a column of air. Find the height of the air column.

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[1] A toy Cartesian diver may be made as follows:—Divide a nut into two portions, take out the kernel, fasten the two parts of the shell with sealing wax so that no air can enter, and make a small hole about the size of a pin head through one end. Fasten two threads to the nut, and from these hang a toy doll. Place in a jar of water so that the small hole is under water. If necessary, add a small weight to the doll to make the nut sink enough.

CHAPTER VI

HEAT

EXPERIMENT **63**

The Bunsen Burner

Apparatus—Glass Tube, Matches, Cardboard, Porcelain Basin, Wire Gauze.

LIGHT an ordinary gas jet and a bunsen burner. Notice the difference between the two flames. Sketch the flames, marking the different zones.

(1) Hold a glass tube or a porcelain basin in each flame for two or three seconds. What can you infer?

(2) Close the holes at the bottom of the bunsen burner. Hold a piece of cardboard in the flame for two or three seconds. What happens? Open the holes, and hold the cardboard in the flame. Is there any difference?

(3) Light a piece of thick brown paper, let it burn for a little, and then extinguish the flame, so that the paper smoulders and gives off a dense smoke. Hold the paper beside one of the holes of a lighted bunsen burner. What happens to the smoke? What is in the tube of a bunsen burner besides gas?

(4) Hold a piece of cardboard for a second in the flame, about 1 inch from the top. What is the shape of the mark? Hold the cardboard about 1 inch above the top of the tube. What would you infer from the shape of the two marks?

Hold a match or a rod of wood in the same spots as the cardboard. What happens?

As quickly as possible introduce the head of an unused match into the middle of the flame about $\frac{1}{4}$ of an inch above the tube. What part of the match catches fire first?

(5) Hold a piece of narrow glass tubing obliquely, with one end in the middle of the flame about half-an-inch above the top of the burner. Bring a lighted match near the other end of the glass tube. What happens? Repeat the experiment near the top of the flame. What can you infer about the different zones? In which part of the flame would you hold a body which is to be heated?

(6) Light the burner, and press *gently* on the rubber tube, making the flame smaller and smaller. What happens? (Notice the peculiar smell.) Light the burner at the top. What is the colour of the flame? Place your finger cautiously on the metal tube of the burner. [When a burner lights at the foot, turn the gas off, and light again.] Press again on the rubber tube, but at the same time close the holes at the bottom of the burner. What happens?

(7) Close the holes, and press down on the flame a piece of wire gauze. What happens? Repeat with the holes open. Is there any difference?

Turn the gas off, hold the gauze above the burner, turn the gas on, and light it above the gauze. Does the flame pass through? Are your fingers which are holding the gauze hot? Can you give any reason for the flame not passing at once through the gauze?

EXPERIMENT **64**

Effect of Heat on Solids

First Method

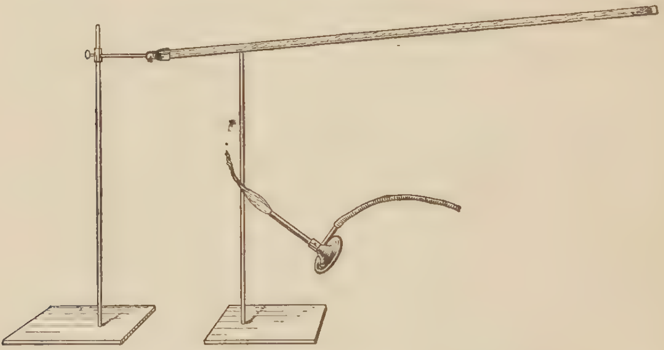
Apparatus—Penny, Calipers.

Open the jaws of a pair of calipers till a penny just passes between them. Hold the penny with a pair of crucible tongs, or lay it on a pipeclay triangle, and heat strongly in a bunsen-burner flame. Try to pass the penny between the jaws of the calipers.

Second Method

Apparatus—Two Retort Stands, Lath, Metre Stick

Remove the rings and clamp from a retort stand. On the top of the rod of the stand place a long, thin wooden lath (a metre stick will do). Fix one end of this lath in the clamp of another stand in such a way that the lath can move vertically round the clamp as a pivot. Place the rod of the first stand near the clamped end of the lath. Measure the height of the free end of the lath above the table.



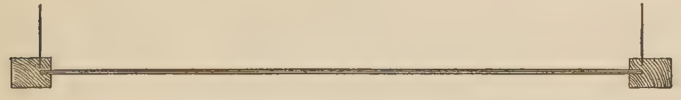
Heat the rod by passing the bunsen burner along it. After heating for a few minutes measure the height of the free end of the lath. What do you infer?

Allow the rod to cool, and turn the lath down till it again rests on the rod. Measure the height of the free end of the lath.

Third Method

Apparatus—Long Metal Rod, two Needles.

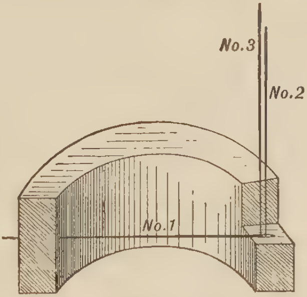
Take a long rod of metal, and place a small piece of wood on each end. This is done by heating the end of the rod and burning it into the wood. Into each piece of wood run a needle, with the point out at right angles to the rod. Measure the distance between the needles with a metre stick.



Heat the rod for a few minutes with a bunsen burner, or by placing the rod in a bath of boiling water, and measure the distance again. Is there any difference?

Exercises

1. Take a flat cork, and cut it into a crescent shape as in the diagram. Stick a needle into the cork so that it is in the position No. 1. Through the eye of this needle insert the point of another needle (No. 2) slightly into the cork so that the needle is upright. Behind this place another needle (No. 3) as a guide. Heat needle No. 1 with a match, and notice how No. 2 moves. What is the cause of the movement?



2. Why is Method 2 better than Method 3?

3. A ball when cold can with difficulty pass through a ring. What happens (1) when the ball is heated; (2) when the ring is heated?

4. What is one of the causes of the sagging of telegraph wires? When is the sagging most apparent?

5. A thick tumbler often cracks when hot water is poured into it, a thin tumbler seldom. Explain.

6. Why are the ends of rails on a railway not placed closely together?

7. When a glass stopper is fixed firmly in a bottle it can be loosened by gently heating the neck of the bottle. Why?

8. How is the iron tyre placed on a cart wheel?

9. If you have seen iron water pipes being laid in the streets, explain how the pipes are joined together.

EXPERIMENT **65**

Effect of Heat on Liquids

Apparatus—Flask, Glass Tube,[1] Rubber Cork with Hole.

Push the glass tube through the cork till the lower end of the tube is level with the bottom of the cork. Fill the flask with coloured water, and push in the cork till the water stands up in the tube. If you are careful there should be no air bubbles in the flask or the tube. (If you cannot get rid of the air bubbles try this method: Allow water to run from the tap into the full flask, and while the water is running push in the cork.)

Mark the level of the water in the tube with thread or a strip of gummed paper. Place the flask on a tripod stand with wire gauze, and heat gently. What happens? Stop heating when the water is 2 or 3 inches from the top of the tube. What happens? What is the reason? Allow the flask to cool. How far does the water fall?

When the flask is cold plunge it quickly into a large basin of hot water. Watch the movements of the water in the tube. Can you explain what happens?

EXERCISES

1. Repeat the experiment, using alcohol.

2. From the last part of the experiment can you tell whether a liquid or a solid expands the more?

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[1] The ends of glass tubes should always be rounded by heating for a few seconds in a bunsen flame.

3. What happens when a kettle full of cold water is heated?

4. Explain why the Relative Density of hot water differs from that of cold water.

5. Prove your answer to Ex. 4 in the following way:—

In a tall, narrow beaker place some cold water coloured blue with indigo. On the top of this water place a round piece of paper just large enough to go in the beaker and not touch the sides. Attach a thread to the edge of this paper.

Pour some hot water coloured red with magenta gently on the top of the cold water. This is done by allowing the hot water to run down a glass rod with one end touching the paper. By doing this the hot water does not mix with the cold. Gently remove the paper. [What is the use of the paper?] What happens?

Repeat the exercise, pouring cold water on the top of hot water.

If you wished to mix quickly some hot and some cold water, which one would you pour into the other?

6. A thousand grammes of hot water are poured into a litre flask. Is the flask too large or too small?

EXPERIMENT **66**

Effect of Heat on Gases

Apparatus—Flask, etc., used in last Experiment.

Take an empty flask, and push into it a cork with a tube through it as in last experiment. If the air in the flask is heated you cannot tell what happens, because you cannot see it.

Take out the cork with the tube attached, and dip the cork into coloured water. Place your finger on the top of the tube, and lift the tube. What have you in the tube at the other end? Still keeping your finger on the tube, insert the cork with the tube in the flask, and remove your finger. What happens to the small thread or column of water? Mark the position of the column of water.

Heat the flask by holding it in your hands. What happens?

Take your hands away before the water is too near the top of the tube. Does the water go up or down the tube? When the air has cooled, where is the thread of water?

Exercises

1. Repeat the experiment, using coal gas.
2. Take the same flask, and insert the cork and tube. Invert, and place the end of the tube in a flask of coloured water. Heat the flask by holding it in your hands. What happens? On cooling the flask, what happens to the water?
3. Take a thin paper bag, half fill it with air, and close the mouth by holding it tightly in your hand or tying it with thread. Place the bag near a flame or a fire. Explain what happens.
4. On a hot day it is usual not to inflate a bicycle tyre so much as on a cold day. Why?
5. A toy balloon is blown up, and the mouth tied. It is held near a fire. What happens?

EXPERIMENT **67**

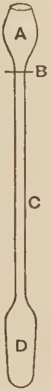
To construct and use a Thermometer

Apparatus—Thermometer Tube with Bulb at bottom and Cup at top, coloured Alcohol or Mercury, Thermometer (Centigrade).

Place some coloured alcohol (or mercury) in the cup A. Heat the bulb D very gently for a second. What happens? Cool. Repeat this heating and cooling till the bulb and the stem are full of alcohol. Pour out any alcohol which is in A.

Heat the stem at B in a bunsen flame, and draw it out till the bore at B is very narrow. While doing this the alcohol in the tube will spurt, but no harm is caused.

Place the bulb and stem in hot water into which you can just comfortably dip your finger. [If mercury be used, heat the bulb in the flame till the mercury boils.] When the alcohol fills the tube, and has ceased to expand, and while the bulb is in the hot water, quickly close the tube at B by heating it in a flame (a blow-pipe flame if possible). Then, by heating, draw off the cup A and round the end B.



The instrument you have made is called a *Thermometer.* When the alcohol has cooled, does it fill the tube? What is in the tube above the alcohol? Would the thermometer work if there were air above the alcohol or if the stem were open at the top? In the thermometers you have seen what liquid was used? Is mercury used for ordinary house thermometers? Can you give any reason for not using it? Examine the laboratory thermometer given you. What liquid is used in it?

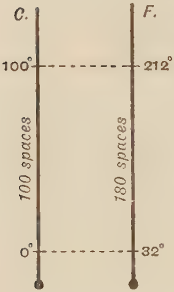
Take the thermometer you have made, and bring it for a second or two cautiously near steam issuing from water boiling in a beaker. Can you now give a reason why alcohol is not used in making thermometers for the laboratory?

Take the laboratory thermometer, and place it in melting ice. This is done by breaking some ice in small pieces and putting them in a funnel. Then place the thermometer so that the mercury is covered with the ice, and wait till the mercury is steady. What number is opposite the top of the mercury? This number (o) is called the *Freezing Point.*

Test if the same number is got with your neighbour's thermometer. How would you find the freezing point on the thermometer you have made? Find it. The freezing point is called a *fixed* point on the thermometer. Why?

Hold the laboratory thermometer in boiling water. At what number does the mercury stand? You will probably find that the mercury does not stand quite steady, but moves up and down a little. Can you explain this? If you wanted to find the exact point at which the mercury stands, what would you place round the thermometer? The number you have found should be near 100. 100 is the exact number. This is called the *Boiling Point* (see Exp. 72). The thermometer you have is called a *Centigrade* (= 100 steps) thermometer, because the length between the freezing point and boiling point is divided into 100 parts. Each part is called a *degree*, which is written 1°. Remember that a degree on a thermometer is not a fixed length like a centimetre, and it has nothing to do with an angle. Write a definition of a degree.

Get a Fahrenheit thermometer, and notice the numbers opposite the two fixed points. How many degrees are between the freezing and boiling points? Compare a degree on the Centigrade (C.) scale and on the Fahrenheit (F.) scale.



The graduations are continued below the freezing point and above the boiling point. Thus 40 degrees below 32° F. is marked −8° (*i.e.* 32 − 40).

Sometimes it is necessary to find the reading on one kind of thermometer which corresponds to a reading on the other.

0° Centigrade corresponds to 32° Fahrenheit.
100° ” ” 212° ”

∴ 100 divisions on the Centigrade scale = 180 divisions on the Fahrenheit scale.

Suppose we wish to convert 60° C. into the Fahrenheit scale. Then, by proportion, 60 spaces from the freezing point on the Centigrade scale $= \frac{60 \times 180}{100}$ (= 108) spaces from the freezing point on the Fahrenheit scale. But the freezing point on the Fahrenheit scale is 32.

$$\therefore\ 60^\circ \text{ C.} = (108 + 32^\circ) \text{ F.} = 140^\circ \text{ F.}$$

Try now to convert 140° F. into the Centigrade scale.

THE USE OF A THERMOMETER

In one beaker place 50 c.c. of water and in a similar beaker place 100 c.c. of water. Place the beakers on two tripod stands with wire gauze, and in each beaker place a Centigrade thermometer. Note the reading on each thermometer.

Light two bunsen burners so that the flames are the same height, and place one under each beaker. After two minutes take the readings. Are they the same? Which is the higher?

Remove the beakers from the tripod stands, allow the water to cool, and then place the beakers each on the other tripod stand. Note the readings after two minutes. You will find that again the reading is higher in the 50 c.c. beaker. Now the bunsen burners were equal, so that the heat supplied to the water in each beaker was the same. Does a thermometer tell or measure the heat in a body?

Dip a finger in each beaker. In which is the water the hotter? Does a thermometer tell anything about the hotness of a body?

When one body is hotter than another the reading of a thermometer is higher for the hotter body, and the hotter body is said to be at a higher *temperature* than the other body.

EXERCISES

1. Hold a thermometer (*a*) vertical, (*b*) horizontal, (*c*) inverted, and take the reading in each case. Does the position of the thermometer make any difference in the reading? [See Exp. 19 for position of the eye.]

2. Find the readings on the Centigrade scale corresponding to 60° F., $-5°$ F., 12° F., 32° F., and the readings on the Fahrenheit scale corresponding to 40° C., 0° C., 150° C., $-8°$ C. Find what temperature is marked the same on the two scales.

[Let $x°$ = reading on the Centigrade scale, then $\frac{180x}{100} + 32 = x$.]

3. Graduate the thermometer you have made by placing it

in a beaker of water with a Centigrade thermometer. Gum a strip of paper along the stem, and tie each end with thread in case the paper becomes loose. Heat the water gently, and when the Centigrade thermometer indicates 10°, 20°, 30°, etc., make a mark on the paper opposite the top of the alcohol. Fix the thermometer to a frame of wood.

4. Take the reading of a thermometer at twelve o'clock every day for a week, and draw a graph of the results. If possible, take readings on both Centigrade and Fahrenheit scales, and compare the graphs.

5. Construct a graph to convert Centigrade readings into Fahrenheit, and *vice versa*, and use it to find the answers to Ex. 2.

6. Give some reasons why mercury is used in thermometers. Would a solid or a gas do as well as a liquid?

7. Place some water in a beaker, and heat gently. Read the temperature every fifteen or thirty seconds. [This is best done by two pupils. One gives the time, the other notes the temperature.] Heat to the boiling point, and let it boil for two or three minutes. Draw a graph of temperature with time.

Let the water cool by placing the beaker in a basin of cold water, and note the temperature every fifteen or thirty seconds. With the same units and the same axes as before draw a graph of temperature with time. Compare the graphs of heating and cooling. Notice the difference of the curves. If possible, have a Centigrade and a Fahrenheit thermometer in the beaker, and take the two readings, and draw the two graphs.

EXPERIMENT **68**

Effects of Heat—Change of State

Apparatus—Ice, Thermometer, Tripod Stand, Beakers.

First Method

Break some ice into pieces not larger than a marble, dry the pieces with a cloth, and fill a medium-size beaker with them. Insert the bulb of a thermometer into the beaker so that the mercury is surrounded by the ice, and note the reading when the mercury is steady.

Place the beaker on a tripod stand and heat for a few seconds with a very small flame. Take away the flame, stir well with the thermometer, and note the reading *when the mercury remains steady*. Stir again and take a second reading to be sure that the mercury is steady. In taking the reading do not allow the thermometer to touch the bottom of the beaker. (Why?)

Heat again for a few seconds, and take the reading as before.

Repeat this till all the ice is melted.

When does the temperature rise above freezing point? Has ice a definite melting point?

Note.—You will not get good results if you take the readings before the mercury is steady or if you allow the heat from the bunsen to affect the thermometer while you are taking the readings.

Does the ice float or sink in the water? Which has the greater density? Can you tell then which occupies the greater volume, 1 lb. of ice or 1 lb. of water? During winter water pipes often burst. Does this happen when the water is freezing, after it is frozen, or after the ice has changed back into water?

Second Method

Place some pieces of melting ice in a beaker, and note the temperature.

Warm a beaker of water, and note its temperature.

Pour a few drops of the warm water into the beaker containing the ice, and stir well with the thermometer. Note the reading. Stir again, and note the reading after half-a-minute. Again pour a very little of the warm water among the ice, and stir well. Take two readings as before.

Repeat till the ice is all melted.

When does the reading remain above the freezing point?

Has any heat gone into the beaker containing the ice? What is the effect of this heat?

Exercises

1. Find if ice or water occupies more space in the following way:—Fit a rubber cork with one hole to a narrow test-tube. Through the cork pass a glass tube which has a very narrow bore. Half fill the test-tube with water, and on the top of the water pour oil till the test-tube is full. Insert the cork so that the oil stands up the tube. Note the level of the oil in the glass tube. Place the test-tube in a beaker full of ice. Note the level of the oil every few minutes till the water freezes.

2. To find the relative density of ice put some paraffin oil into a burette. Place the burette in a beaker containing ice and water so that the oil is under the ice-cold water. After several minutes note the level of the oil in the burette. Break some ice into pieces small enough to go into the burette, dry each piece carefully, and drop into the burette. Note the volume of ice added. Take the burette away from the cold water, and melt the ice by holding the burette in your hand. Then replace the burette in the beaker to cool the oil and water. Note the volume of water got from the ice. Hence find the relative density of ice.

EXPERIMENT **69**

To find the Melting Point of Solids

Apparatus—Wax, Evaporating Basin, narrow Test-tube, Thermometer.

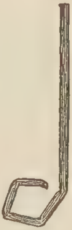
Heat some wax gently in an evaporating basin. Does it change its state? Drop a piece of solid wax into the melted wax. Does it sink? Does wax increase or decrease in density when it melts?

Dip the bulb of a thermometer in the melted wax, and note the temperature. Lift the thermometer out of the basin. You will notice that some of the liquid wax clings to the bulb. Note the reading on the thermometer. Is it steady? Look at the bulb and you will notice that suddenly the wax on it turns white. Why? At the same instant note the reading. This temperature is called the solidifying point of wax.

Take a narrow test-tube, and heat the middle of it in a blow-pipe flame, turning it round in the flame till the glass is quite soft. Take it out of the flame, and at once draw the two halves apart. You should get a fine hair-like tube.

Cut off a part of this 2 or 3 inches long, and dip the end in melted wax. Fasten the tube with the wax in it to the bulb of a thermometer with a piece of thread. Place the thermometer in a beaker of water, and fasten it in a clamp so that the bulb is about 1 inch above the bottom of the beaker.

Heat the water gently, and stir it constantly with a glass rod. (See diagram.) Watch the wax in the capillary tube. At the instant that it melts note the temperature. When the wax melts it becomes clear, so that the change is easily noticed. Take away the flame from the beaker. Note when the wax turns solid. If this reading is not the same as the former one take the mean of the answers as the melting point of wax.



Find the melting point of sulphur in a similar manner, but instead of water use sulphuric acid or glycerine. If sulphuric acid is used, the small tube must be fastened to the thermometer with a platinum wire. (Why will thread not do?) After you have found the melting point you should be able to say why water cannot be used in the beaker.

Note.—Some substances have no definite melting point—*i.e.* there is no fixed temperature at which they change from a solid into a liquid. Iron becomes like a paste when it is heated. Has glass a definite melting point? Name some other solids which have no melting point.

EXPERIMENT 70

To find the Effect of Solids on the Melting Point of Ice

Apparatus—Ice, Filter, Funnel, Thermometer, Salt.

Place some pounded ice in a funnel, and note the temperature. Add a handful of salt to the ice. What is the new reading? You will see from the reading that clean ice should be used in finding the reading 0° on a thermometer. Is it a good practice to sprinkle salt over pavements which are covered with snow?

Why does the sea seldom freeze even during a severe frost?

EXERCISES

1. Repeat the experiment, using other salts (*e.g.* sodium sulphate and calcium chloride) instead of common salt.
2. Repeat the experiment, using sand instead of salt.

EXPERIMENT 71

To find the Effect of Pressure on the Melting Point of Ice

Apparatus—Block of Ice, a 28-lb. or a 56-lb. Weight, strong Wire.

Place the block of ice so that the two ends are supported on wooden props (the backs of two chairs will do). Loop a wire round the middle of the block, and attach the ends of the wire to the heavy weight, which is thus supported by the block of ice. Gradually the wire slips through the block of ice. After some considerable time you will find that the wire slips right through the ice, so that the ice is divided into two parts.

Do the two parts fall asunder? Try to break the block along the path of the wire. Is it easy? Can you see the path of the wire?

When the wire presses against the ice it melts the ice under the wire, and the water formed escapes above the wire. What happens to this water? What is the effect of pressure on the melting point of ice?

Can you now explain why the wheel tracks on snow are generally covered with a sheet of ice?

Note.—In substances which expand on melting—*e.g.* paraffin wax—the effect of pressure is to raise the melting point.

EXERCISES

1. Take two pieces of ice with flat surfaces. Press the two pieces together. What happens? Take other two pieces of ice, and press them together in a basin of water. Explain the result.

2. Why is it easy to make a snowball when the snow is near its melting point, but difficult to make the snow stick together when it is very cold?

EXPERIMENT **72**

To find the Boiling Point of Liquids

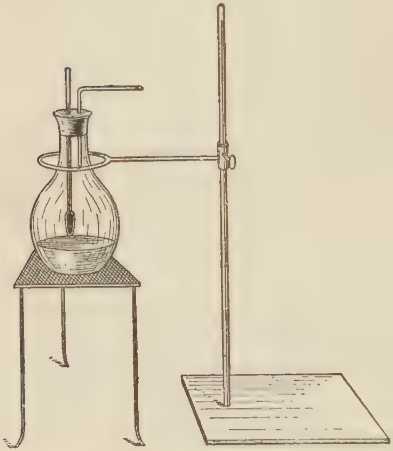
First Method

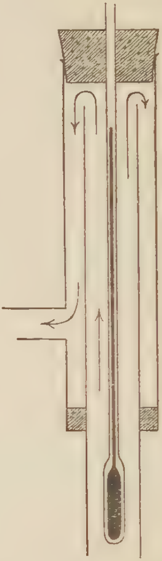
Apparatus—Boiling Tube or Flask, bent Glass Tube.

Take a long boiling tube or flask, and fit an ordinary cork to it. Make two holes through the cork, and insert a bent glass tube through one and a thermometer through the other.

Place a little water in the boiling tube or flask, and push down the thermometer till the bulb is a little above the water.

Fix the boiling tube or flask in a clamp, and boil the water. Note the reading on the thermometer. Can you state any disadvantage of this method?





Second Method

You are given the apparatus shown in the diagram. Fit it into a flask which contains some water, and boil. Notice the passage of the steam. Push a thermometer through the top cork till all but 1 inch is surrounded by steam. When the mercury is steady note the reading.

Repeat the experiment, using alcohol, turpentine, etc.

Repeat the experiment, using glycerine. Use a thermometer which reads to 400° C. Do you notice any peculiarity about the readings? Smell the boiling glycerine. [If the glycerine is not absolutely pure it decomposes slightly on boiling.]

EXPERIMENT 73

To find the Effect of Impurities on the Boiling Point of Water

Apparatus—Same as Exp. 72.

Put some pure water into the flask, heat, and take the temperature (*a*) of the boiling water and (*b*) of the steam. Put some pieces of (1) glass, (2) metal, (3) sawdust into the water, boil, and again take the two temperatures.

Instead of the glass put a handful of (1) salt, (2) sugar, (3) gelatine, into the water, boil, and note the two temperatures. What is the effect of the solids on the temperature? Can you now give the reason why you place the thermometer in the steam and not in the boiling water when you wish to find the boiling point?

EXERCISES

1. Repeat the experiment, adding two or three handfuls of calcium chloride.
2. Repeat the experiment, using alcohol instead of water.
3. What would you expect the boiling point of sea water to be?

EXPERIMENT 74

To find the Effect of Increase or Decrease of Pressure on the Boiling Point of Water

Apparatus — Strong round-bottomed Flask, well-fitting Rubber Stopper with two Holes, Air Pump, Evaporating Basin containing strong Sulphuric Acid, Thermometer to read $\frac{1}{10}°$.

(1) Through one of the holes in the rubber cork pass a thermometer, and through the other a small piece of bent glass tube, as in Exp. 72. Put some water in the flask, insert the cork tightly, and boil the water. Note the temperature.

Now close the end of the glass tube through which the steam has been escaping by placing over it a piece of rubber tubing with a clip. Note the temperature. *When it has risen less than 1° take off the clip.* What do you notice about the issuing steam when you take off the clip? What would happen if you forgot to take off the clip?

(2) Take the same flask, put some water in it, boil for a few minutes, turn out the gas, and at once insert a solid rubber cork, or a cork with a thermometer (see Fig. 1, Exp. 72).

Place the flask inverted on the ring of a stand above a trough of water. What is inside the flask? Compare the pressure of the air inside the flask with the pressure of the air outside.

Pour a little water on the flask. What happens? Stop pouring the water. Is there any change? Continue to pour water on the flask till the water inside the flask remains at rest. Take out the cork. Note and explain what happens. Can you explain why the water in the flask boils when cold water is poured on the flask?

(3) Heat some water in a beaker till it is nearly at the boiling point. Place the beaker under the receiver of an air pump along with a basin containing strong sulphuric acid. (The acid absorbs all the water vapour.) Exhaust the receiver. What happens to the water? What is the temperature of the water when it boils inside the receiver?

EXERCISES

1. From Exp. 73 you found that the steam from boiling water (impure or pure) is at 100° C. Is this always true? If not, what is the factor which alters the temperature?

2. If the flask used in Exp. 73 (second part) is not strong it may burst. Why? In what direction will it burst? Will a steam boiler burst from the same cause? Will the temperature of the steam in a boiler be 100° C.? Explain.

3. With the same stove will it take the same time to boil a pan of water at the top of a high mountain as at the foot? At which place will it be easier to boil potatoes?

4. Give two methods of raising the temperature of boiling water.

5. By means of a bent pipette a little water is inserted in a barometer. Why does the water rise to the top? What do you think will happen to the water when it gets to the top? Try the experiment.

EXPERIMENT **75**

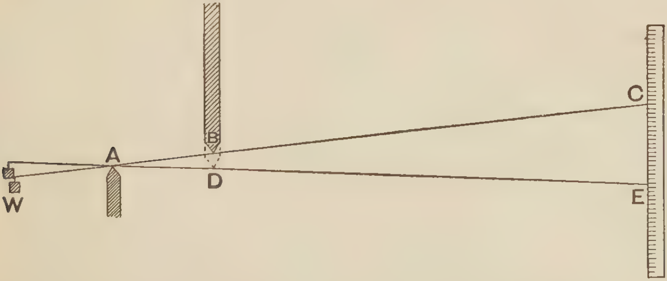
To find the exact Increase in Length of a Metal Rod when it is heated

Apparatus—Glazebrook's Apparatus.

Examine the apparatus.

Measure the length of the metal rod between the sharp point B and the point near the other end where it is clamped. Take the temperature of the room. (This is also the temperature of the rod.)

The sharp end of the rod rests on a lever ABC, which is balanced by a weight W hung on one end. The lever turns about the point A. Measure AB and AC, and get the value of the fraction $\frac{AB}{AC}$. Measure the height of the end C above the bench when the rod is placed in position.



Pass steam from a flask through the jacket for a few minutes, take the temperature of the steam, and measure the height of the end of the lever. You will find that the end has moved downward owing to the expansion of the rod. Suppose the new position of the lever is ADE. Then the end of the lever has moved CE, but the rod has moved only BD. Find the length of CE. By geometry it can be proved that $\frac{AB}{AC} = \frac{BD}{CE}$. From this we can find the expansion BD.

Let the difference of temperature of the rod at the beginning and the end of the experiment be $t°$ C., and let the length of the rod at the beginning be l cm.

Then if l cm. of metal expand BD cm. for a rise of $t°$ C., how much will 1 cm. of metal expand for a rise of 1° C.?

This answer is called the *coefficient of linear expansion.*

Find the coefficient of linear expansion of rods of various metals—*e.g.* iron, copper, brass. If a Fahrenheit thermometer be used, will the coefficient of expansion be the same?

What will be the relation between the two coefficients?

EXERCISES

1. Two strips of copper and iron of exactly the same length are riveted together, one on top of the other. The compound strip is heated. What happens?

2. The coefficient of linear expansion of steel is ·0000123. A steel yard stick is graduated when the temperature is 15° C. What will be the length on a day when the temperature is 0° C.?

3. What do you mean by the coefficient of surface expansion? A square sheet of metal is one unit length. It is heated through 1°, and the length increases by a. What is the length of the side after heating? What is the new area and the increase of area? If the sheet is iron, $a =$ ·0000122. What is a^2? Can a^2 be neglected? If so, how can you measure the coefficient of expansion of area?

4. What is meant by the coefficient of cubical expansion? How would you find it? (See Ex. 3.)

5. A cube of brass has an edge of 5 cm. at 20°. What is the total surface area and the volume (1) at 0° C.; (2) at 100° C.? (linear coefficient of brass = ·000019).

6. An iron rod 40 feet long is firmly bolted to two walls of a house. The rod is heated. What happens? Tell how you could make vertical the walls of a house which bulge outward or inward.

7. The distance between two telegraph poles on the railway is 58 yards. A copper wire is stretched tightly in winter. What is the length of the wire in summer when there is a difference in temperature of 30° C.? (linear coefficient of copper = ·000017).

8. If a platinum wire is inserted into the end of a glass tube, and the tube sealed and cooled, the glass does not crack, but if another metal is used instead of platinum the glass will probably crack. Can you explain this?

EXPERIMENT **76**

To measure the Expansion of Liquids

First Method

Apparatus—Narrow Glass Tube about 15 inches long and about $\frac{1}{20}''$ bore, tall Jar, Thermometer.

Close one end of the tube, and half fill it with coloured water. (See method of filling thermometer, Exp. 67.) Place the tube along a strip of wood, and tie with thread.

Fill the tall jar with water, and add some pieces of ice till the temperature is 0° C. Place the tube in the jar so that all the water in the tube is covered. Note the temperature, and put a mark on the wood opposite the surface of the water in the tube.

Pour a little hot water into the jar, stir well, note the temperature when steady, and at the same instant mark the level of the water. Repeat this up till 100° C. Measure the length of the column of water for each reading. Are the lengths proportional to the volumes?

Arrange your results in a table.

Temperature	Length of Column	Rise of Temperature	Increase of Length	Increase of Length for Rise of 1°

From the table find the average increase of volume for a rise of 1°. Also find what fraction this increase of volume is of the volume at 0° C.

Repeat with other liquids—*e.g.* mercury, alcohol. Are the fractions always the same? The fraction found is called the *coefficient of cubical expansion* or the *coefficient of dilatation.*

Have you considered the expansion of the glass tube? Are the results you have found greater or less than the real coefficient of expansion of the liquids?

Draw a graph of rise of temperature with increase of volume.

Second Method

Apparatus—Weight Thermometer or Density Bottle, Mercury, Beaker.

Weigh the weight thermometer empty.

Hang it on the ring of a stand so that the bottom rests on the gauze of a tripod stand and the open end dips under mercury contained in a beaker. Fill the thermometer with mercury by heating and cooling in the same way as an ordinary thermometer. Do not take away the beaker till the thermometer is quite cold. Note the temperature of the air ($t°$).[1]

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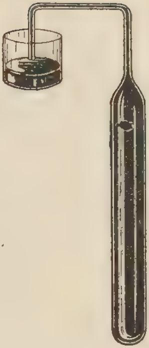
[1] For very accurate results the temperature at the beginning should be 0° C. This is got by placing the weight thermometer in a beaker containing melting ice.



Pass a piece of string under the bend, and lift the thermometer to the balance, and weigh. Why must you not touch it with your hand?

Now place the thermometer in a beaker of water so that the bent tube is over another beaker containing mercury. Heat the water to the boiling point. What happens to the mercury? Note the temperature of the boiling water ($T°$). Let the water cool. Take out the thermometer, dry it very carefully, and weigh.

Arrange in a table.

Mass of empty thermometer = ... gm.
,, thermometer + mercury (1st) = ... gm.
∴ ,, mercury at $t°$ C. (say) = a gm.
,, thermometer + mercury (2nd) = ... gm.
∴ ,, mercury at $T°$ C. (say) = b gm.
∴ ,, mercury expelled = ... gm.

Then a gm. of mercury at $t°$ occupy the same volume as b gm. at $T°$.

∴ Any mass of mercury at $T°$ occupies $\frac{a}{b}$ of its volume at $t°$.

If the original volume at $t°$ be called 1, then the increase of volume for a rise of $(T-t)° = \frac{a}{b} - 1 = \frac{a-b}{b}$.

∴ Increase of volume for a rise of $1° = \frac{a-b}{b(T-t)}$.

∴ Coefficient of Dilatation $= \frac{\text{Increase for rise of } 1°}{\text{Original Volume}} = \frac{\frac{a-b}{b(T-t)}}{1}$

$= \frac{a-b}{b(T-t)}$.

EXERCISES

1. A weight thermometer contains 177·07 gm. of mercury at 12° C. and 174·7 gm. at 100° C. Find the coefficient of cubical expansion of mercury.

2. In your experiment the coefficient of lineal expansion of glass is ·0000087. Find the real coefficient of expansion of mercury.

3. From the graph of the experiment (first method) find the length of the column of water in the tube at 0° C.

EXPERIMENT 77

To study the Expansion of Water

Apparatus—Long Thermometer Tube with a Bulb about 7 or 8 cm. long, Thermometer to read $\frac{1}{10}$°.

Take a thermometer tube with narrow bore, and about 20 cm. long, and having a long bulb attached to it. By gently heating and cooling fill about one-seventh of the bulb with mercury and the rest with water, and keep the end of the tube under water till all is cold. Behind the tube place a strip of millimetre paper, and tie it on with thread.

Place the bulb in a jar of cold water (about 10° C.), and note the surface of the water in the tube. Cool the water in the beaker by adding two or three small pieces of ice. When the ice has melted note the temperature and the height of the water. Add some more ice to reduce the temperature by a fraction of a degree. Take the readings, and repeat till the temperature of the water is nearly 0°. Then allow the temperature to rise by small fractions of a degree (adding a little warm water if necessary), and take the readings. Arrange the heights and the temperatures in a table, and draw a graph of the two. At what temperature is the volume of water the least? At what temperature is the density of water the greatest?

Note.—This is the temperature at which 1 c.c. of pure water weighs 1 gm. (See Exp. 37.)

EXERCISES

1. Find the maximum density point of water by Hope's Apparatus.
2. Repeat Hope's Experiment, but instead of pure water use water with (say) 10 per cent. of salt dissolved in it. Does the presence of the salt make any difference in the maximum density point?
3. Explain the process by which a deep pond becomes frozen.
4. It has been noticed that a small pool of water on the surface of a glacier grows deeper and deeper with every return of the sun. Can you explain?
5. Give some reasons why water is not a good liquid to use in a thermometer. Is it possible to use a water thermometer?

EXPERIMENT **78**

To find the Coefficient of Expansion of Air

First Method

Apparatus—Thermometer Tubing about 1 foot long and narrow Bore, Mercury, Thermometer, tall Jar.

Suck about 1 inch of mercury a quarter of the way up the tube, place your finger on the bottom end, and as quickly as possible seal the other end. Allow to cool. Fix the tube, open end upwards, on to a strip of wood with thread. In the tube you have a column of air under a certain pressure. What is the pressure? Is it constant?

Place the tube and a thermometer in a jar containing water with pieces of ice, so that the column of air is under the water. Put a mark on the wood at the top of the column of air, and note the temperature.

Pour some hot water into the jar till the temperature is a few degrees above zero. Stir the water well, take the temperature, and at the same instant mark the top of the column of air. Repeat this for a rise of a few degrees up to 100° C.

Arrange in a table.

Temperature	Length of Column of Air	Increase of length for rise of t° C.	Average Increase for rise of 1° C.

Is the increase of length proportional to the increase of volume? From your results find the coefficient of expansion of air under a constant pressure.

Second Method

Apparatus—Round-bottomed Flask fitted with Rubber Cork with one Hole, short Piece of Glass Tube with Rubber Tubing and Clip.

Dry the flask by passing hot air through it, insert the cork with the piece of glass tube, and open clip, and place up to the neck in a large beaker or can full of water. Clamp the flask to keep it under the water. The flask is now full of cold air.

Heat the water in the beaker till it boils, and let it boil for some minutes. Take the temperature of the water. Close the clip as near the top of the glass tube as possible. Take the flask out of the hot water, and place it in a large basin full of cold water, so that the clip and rubber tube and cork are under water. Open the clip What happens?

Push the whole flask under water, and hold for two or three minutes till the air in the flask has the same temperature as the water in the basin. Hold the inverted flask so that the levels of the water inside and outside the flask are the same. Why do you do this? While in this position close the clip in the same place as at first. Take the temperature of the water in the basin.

Measure the volume of the water in the flask, also measure the capacity of the flask by placing it without the cork under the water in a basin. When it is full of water, and still in the basin, insert the cork and clip as before. Then measure the water in the flask.

Having got the capacity of the flask and the volume of the water which rushes in, how would you find the volume of the air which is left in the flask when the water rushes in?

What is the temperature of this air? When this air was heated in boiling water, what volume did it occupy? Find, then, the increase of volume, also the increase of volume for a rise of 1° C., and so get the coefficient of expansion.

Example:

Capacity of flask = 420 c.c.
Volume of water which rushed in = 99 c.c.
∴ Volume of cold air in flask = 321 c.c.
Temperature of cold air = 15° C.
,, hot air = 100° C.

∴ 321 c.c. of air at 15° expanded 99 c.c. for a rise of 85° C.
∴ 321 c.c. ,, ,, $\frac{99}{85}$,, ,, 1° C.

∴ Coefficient of Expansion $= \dfrac{\frac{99}{85}}{321} = \dfrac{1}{\dots}$.

Repeat the experiment, using coal gas.

The results you have found are stated in a law called *Charles's Law.* Can you write the law?

Note.—For complete accuracy the water in the large basin should be at 0° C.

Exercises

1. Find the volume that the air in the above experiment would occupy at 0° C.

2. By calculation find the temperature to which air must be cooled so as to have no volume. (This temperature is called *Absolute Zero.*)

3. Take the results of the First Method, and construct a graph of temperature and volume. From the graph find the temperature at which air should have no volume. Compare with Ex. 2.

4. A volume of air is heated till it becomes two volumes. Through what rise of temperature will it be heated?

5. If 300 c.c. of air are cooled from 30° C. to – 30° C., what is the new volume?

6. It has been suggested that the readings on a thermometer should begin at absolute zero—that is, absolute zero should be called 0°. What will 0° C. be on the absolute scale? Express 100 C., – 100° C., 4° C. in the absolute scale.

A volume of air is 100 c.c. at 280° absolute. What is its volume at 560° absolute? Is there any relation between the volume and the absolute temperature?

7. How can Boyle's Law and Charles's Law be combined? At a temperature of 0° C. and 760 mm. pressure the volume of a quantity of air is 100 c.c. What will be the volume at 100° C. and 750 mm. pressure? At what temperature will its volume be 200 c.c. under 755 mm. pressure?

EXAMINATION PAPER ON HEAT (Exp. 63-78)

1. Explain the principle of a gas stove or an incandescent burner.

2. State all the conditions necessary for a good thermometer. Does a mercury thermometer fulfil all the conditions?

3. In Boyle's Law what is taken as constant? If this is not constant, what other law comes into operation? Explain the effect of this law.

4. Why does a pond begin to freeze at the top? Explain the process of the freezing. What would happen if ponds, etc., froze first at the bottom?

5. Explain how you would find the melting point of iodine. Can you find the melting point of wood?

6. "Heat expands and cold contracts." Discuss the truth of this statement.

7. How would you find if the fixed points on a thermometer were correct? A thermometer is allowed to stand in a beaker of water which is on a tripod stand. The water is heated by a bunsen burner. Does the thermometer indicate the correct temperature of the water? If it does not, how would you remedy the mistake?

8. Explain why there is a draught up a chimney when there is a fire in the grate. A lighted candle is placed near the top of a door (slightly open) leading from a hot room into a cold hall. What will you notice? Will the effect be the same if the candle is placed near the bottom of the door?

9. A quantity of air occupies 500 c.c. at 15° C. and 760 mm. At what temperature under a pressure of 755 mm. will it occupy 1000 c.c.?

10. A piece of ice is shaped into a uniform rod and put upright into a jar of water. Will it float? If so, what fraction will be under water?

APPENDIX

EXPERIMENT **79**

The Simple Pendulum

Apparatus—Small Metal Ball with a narrow Hole bored right through, so that a Thread can be passed through it, Thread about 1·5 metres long, two Wood Straight-Edges, Metre Stick, Clamp Stand, Slide Calipers, Watch with Seconds Hand.

(1) *To set up the pendulum.*—Pass the thread through the hole in the ball, tie a knot at one end of the thread, and pull the thread till the knot rests against the ball.

Place two straight-edges together and catch them horizontally in a clamp stand. Insert the thread between the straight-edges and tighten the clamp so that the thread is held firmly between the straight-edges. This allows the pendulum to swing from a *fixed point of suspension.* (A pair of forceps, *e.g.* the forceps in a box of weights, can be used instead of the two straight-edges.)

To get the length of the pendulum, measure the length of the thread between the point of suspension and the top of the ball; find the radius of the ball by a pair of slide calipers and add the two answers. This gives the length of the pendulum.

(2). *To get the time of an oscillation.*—(To perform this experiment two observers are required, one of whom counts the number of swings while the other counts the number of seconds.)

Allow the ball to hang freely. Hold the ball in your hand so that the thread is taut, pull it a few degrees to one side of the vertical, and let it go. It swings to the other side and then returns to your hand. This to and fro movement is called a *complete oscillation* or a *swing-swang*. The movement in one direction only is called a *semi-oscillation* or a *swing*. The distance through which the ball swings in a semi-oscillation is called the *amplitude*. The time for a complete oscillation is called the *period*.

Hold the ball a *few* degrees from the vertical while your neighbour looks at a watch with a seconds hand. When the seconds hand is at an exact minute your neighbour will say "let go," and at the same instant you will let go the ball and count "nothing." When the ball has made a complete oscillation count "one," and so for sixty oscillations. Take a note of the number of seconds, and so find the time of one oscillation.

Repeat the experiment, but allow the pendulum to swing through double the amplitude that it had before. Repeat several times, increasing the amplitude each time.

Arrange your results in a table.

Number of Complete Oscillations	Time of Oscillations	Time of One Oscillation

Has the amplitude of the swing any effect on the time of swing?

(3) *To find the relation between the length of the pendulum and the period.*—Arrange the apparatus so that the length of the pendulum is fully a metre. Find the time of, say, sixty oscillations, and the length of the pendulum. (In all experiments the amplitude should not be more than a few degrees.) Shorten the length of the pendulum by a few centimetres and

repeat the experiment for another number of (say fifty) oscillations. Repeat several times, shortening the length each time.

Arrange your results in a table.

Length of Pendulum (l)	Time of Oscillations	Time of One Oscillation (t)	$\frac{l}{t}$	$\frac{l}{t^2}$

What do you notice about the numbers in the last or the second last column? Which of the following equations is correct :— $\frac{l}{t} = \text{K}$, or $\frac{l}{t^2} = \text{K}$, where K is a constant?

(4) *To find the relation between the length of the pendulum and the number of oscillations in a fixed time.*—Arrange the apparatus so that the length of the pendulum is fully a metre. Count the number of complete oscillations in, say, sixty seconds, and measure the length of the pendulum. Shorten the length of the pendulum by a few centimetres and again count the number of oscillations in sixty seconds. Repeat this several times, shortening the length of the pendulum each time.

Arrange your results in a table.

Length of Pendulum (l)	Number of Oscillations in Sixty Seconds (n)	$n \times l$	$n^2 \times l$

Which of the following equations is correct :—$n \times l = K$, or $n^2 \times l = K$, where K is a constant?

EXERCISES

1. Draw a graph of l and t, and of l and t^2, using the values got in the experiment.

2. Using the equation $\frac{l}{t^2} = K$, find the length of a pendulum which makes a complete oscillation every second. Arrange your pendulum so that its length is the same as the length found, and try if the period is exactly one second. If it is not, alter the length till its period is one second, and measure the length.

3. Find the length of the pendulum of a clock which beats every second. (Here $t = \frac{1}{2}$ second.)

4. A pendulum of a certain length makes fifty swings in a minute. Compare its length with that of a pendulum which makes 100 swings in a minute.

5. A marble timepiece makes 160 ticks per minute. What is the length of the pendulum?

NOTE ON MEASUREMENT OF AREA

In finding the area of any figure by measurement, the length and breadth may not have the digit in the second place of decimals absolutely correct, since this digit is usually got by guessing with the eye (see Exp. 1). In most cases the maximum error will be ·02 cm.—*e.g.* if the correct measurement is 12·65 cm., one pupil may read it as 12·64 cm., and another as 12·66 cm. It is thus absurd to expect the area to be correct to *four* places of decimals, yet the answers are often left in this "too-correct" form. This mistake is made even by those who should know better. The following question is taken from a set of Mensuration Cards published a short time ago:—"How many square centimetres are contained in the given semicircle ABC?" The measurements are to be taken to the nearest millimetre, yet the answer is given as 94·346175 square centimetres.

The pupils should be encouraged to determine the maximum error in their answers. There are several methods of doing this; the following example will illustrate one of the simplest.

"Find the area of a rectangle, the length being 25·24 cm. and the breadth 16·17 cm."

Area = 25·24 × 16·17 sq. cm.

= 408·1308 sq. cm. (if the measurements are absolutely correct).

But the maximum error in the length and in the breadth may be taken as ·02 cm.

∴ Maximum length = 25·26 cm.; maximum breadth = 16·19 cm.

and Minimum length = 25·22 cm.; minimum breadth = 16·15 cm.

∴ Maximum area = 25·26 × 16·19 sq. cm. (1)

and Minimum area = 25·22 × 16·15 sq. cm. (2).

The maximum error may be got by taking either (1) or (2).

If (1) is taken, the maximum error =

(25·26 × 16·10) sq. cm. − (25·24 × 16·17) sq. cm.

= 1 sq. cm. (roughly).

If (2) is taken, the maximum error =

(25·24 × 16·17) sq. cm. − (25·22 × 16·15) sq. cm.

= 1 sq. cm. (roughly).

In either case the maximum error is about 1 sq. cm.

∴ Area = 408 sq. cm. ± 1 sq. cm.

EXERCISES FOR REVISION AND HOME WORK

CHAPTER I

1. Draw a line 1·65 inches long. Make it 0·75 inches longer. Measure the whole length in centimetres and confirm your answer by calculation.

2. Find the number of (1) centimetres in 1 kilometre; (2) millimetres in 1 metre, (3) metres in 1 centimetre; (4) centimetres in 1 millimetre.

3. What is the length in British units (to the nearest foot) of a pole 22 metres long?

4. A chain 65 yards long is sent to France and charged at 1 franc per metre; what is the price (to the nearest franc)?

5. At the Olympian Games the 1·5 kilometre race was won by a British competitor. How many yards did he run?

6. A piece of cloth 30 metres long is sent from France to a London draper, who measures it with a yardstick and finds it to be 33 yards. Is the yardstick correct?

7. Find the perimeter of a rectangle, length 27·94 cm., breadth 16·82 cm.

8. Draw several squares on squared paper. Measure a side and a diagonal of each, and so find the value of the fraction $\frac{\text{diagonal}}{\text{side}}$. Is the value of this fraction the same for all the squares?

9. What is the diameter of a halfpenny? How many rows of halfpennies can be placed on a sheet of paper $6\frac{1}{2}$ inches long and 4 inches broad?

10. Given a map, a pair of dividers, and a straight-edge, how would you find the length of the river Thames?

11. A boy measures the diameter of a ball, and gets the following answers:—(1) 3·74 cm., (2) 3·72 cm., (3) 3·75 cm., (4) 5·74 cm., (5) 3·74 cm. What should he write as the average?

12. What is meant by the "bore" of a tube? The outside diameter of a brass tube is 1·25 inches, and the thickness of the metal is 0·25 inches. What is the bore?

13. How would you find the diameter of a telegraph pole?

14. Find the diameter of a wheel the circumference of which is 4·8 feet.

15. "I measured a beech-tree which was 13 feet in girth, and I was told of another tree which was 5 feet in thickness." Which of the two trees was the thicker, and by how much?

16. The external diameter of a flat ring is 22·16 cm. and the breadth of the metal is 0·82 cm. What is the internal diameter?

17. The external circumference of a flat ring is 25·2 cm. and the internal circumference 18·6 cm. What is the breadth of the metal?

18. A circular racing track is 5 laps to the mile. Find the diameter.

19. A bridge is thrown over the widest part of a circular lake. A man starts from one end of the bridge and walks round the edge of the lake till he comes to the other end of the bridge. This takes him $31\frac{1}{2}$ minutes. How long would he take to walk across the bridge?

20. The minute hand of a clock is 2 feet long. How far does the tip of the hand move in a quarter of an hour?

21. The distance between the hour figures on a clock is 2 cm.; what is the diameter of the face of the clock?

22. A hoop 50 cm. in diameter rolls along the ground and makes fifteen turns before it falls. How far has it travelled?

23. Two circles of diameter, 5 cm. and 10 cm. respectively, are made of wire. The wires are cut and placed together so as to form one circle. Find the diameter of this circle.

24. Three wire circles of 3 cm., 4 cm., and 5 cm. radius respectively are placed together so as to form one circle. Find its radius.

25. A piece of thread which goes exactly round the perimeter of a square of 9·24 cm. side is made to form the circumference of a semicircle (*i.e.* the curved line only). Find the length of the diameter.

26. The thread used in question 25 is made to form the perimeter of a semicircle (*i.e.* the semi-circumference and the diameter). Find the length of the diameter.

27. A cart wheel is 3 feet 10 inches in diameter. What is the length of the iron tyre round it?

28. There are forty-two teeth on the rim of a wheel of diameter 9·5 inches. Find the distance between two teeth next each other.

CHAPTER II

1. How many mm. are in a cm.; how many sq. mm. in a sq. cm.; how many cm. in a mm; how many sq. cm. in a sq. mm.; how many sq. cm. in a sq. metre; how many sq. mm. in a sq. m; how many sq. cm. in a sq. in.; how many sq. ins. in a sq. cm.?

2 What is the difference between the area of a field 100 yards square and that of a field of 100 square yards?

3 "In South America I found the remains of nine great animals on the beach within a space of two hundred yards square." How many square yards would this allow for each animal?

4. Some sea animals are so small that they cover a space equal only to the square of the thousandth of an inch. How many of these animals will cover an area of one square inch?

5. Find the area of a drawing board 2 feet 10 inches long and 1 foot 6 inches wide.

6. Examine the correctness of the statement: 4 feet × 6 feet = 24 square feet.

7. A brick is 9 inches long, 6 inches broad, and 4 inches high. Find the total perimeter and the total area.

8. If I find the area of a table 2 yards long and 4 feet wide by multiplying 2 by 4, what does the answer 8 represent?

9. "One of the rectangular blocks of stone was 2 yards square and 3 feet high." Find the total area of this block.

10. A boy measures a rectangle and finds the length to be 25·26 cm and the breadth 12·13 cm. What should he write as the area?

11 The area of a bench is 24 square metres. If the length is 5 metres 25 cm., what is the breadth?

12 A farmer runs a road 10 feet wide through a cornfield which is 250 yards long. How much ground does the farmer lose?

13 A hearth is covered with thirty-six tiles each 8 inches square. Find the area of the hearth.

14. How many boards 9 feet long and 1 foot wide will be required to cover a floor 27 feet long and 18 feet wide.

15. How many strips of copper 5 cm. by 5 mm. can be cut from a sheet 25 cm. by 30 mm.?

16. If there is a space 2 feet wide left uncovered between the edges of a carpet 5 yards by 3 yards and the walls of a room, find the area of the floor of the room.

17. A door consists of a wood frame surrounding a sheet of glass. The total length of the door is 2·25 metres and the total breadth 1·25 metres. The length of the glass is 1·00 metres and the breadth 0·75 metres. What is the area of the wood frame?

18. Find the area of a parallelogram the base of which is 25·67 cm. and the height 12·15 cm.

19. The area of a parallelogram is 126 sq. cm. The height is 16·25 cm., what is the base?

20. Find the area of a triangle the base of which is 25·20 cm. and the height 4·18 cm.

21. The base of a triangle is 24·79 cm. and the area is 24 sq. cm. What is its height?

22. "I picked up an arrow head on the shore. It was 2·5 inches long and 1·5 inches broad, and therefore twice the size of those found previously." What do you think was the size of those arrows which had been found previously?

23. Find the area of a trapezium if the parallel sides are 2·56 cm. and 5·17 cm. and the height 6·04 cm.

24. A trapezium is 5 cm. high, and the sum of the parallel sides is 15 cm. Find the area of the trapezium.

25. Find the area of an equilateral triangle of 4·4 cm. side.

26. Find the area of a regular hexagon of 8·8 cm. side.

27. A board is 15 inches wide; what length must be cut off to supply a customer who wishes a square yard?

28. A road is 200 yards long; find the area of the path which is 3 feet broad.

29. Find the area of the gable end of a house, given the following dimensions:—height to bottom of the eaves = 25 feet; breadth of house = 18 feet; vertical height of roof (from bottom of eaves) = 12 feet.

30. A circular field is 100 yards broad; find its area.

31. A circular pond is 250 metres in circumference; find its area.

32. The area of a coin is 15 sq. cm.; find its diameter.

33. Which has the greater area: a circle of 6 cm. radius or two circles each of 3 cm. radius?

34. A collar is marked "$15\frac{1}{2}''$ by $2\frac{1}{2}''$." What is the area that is touched by the dressing iron?

35. Find the diameter of a cylinder 20 cm. high if the area of the curved surface is 108 sq. cm.?

36. A cylindrical boiler with flat ends is 3 metres long and 1·6 metres in diameter. Find the total surface area.

37. The external diameter of a flat ring is 6·8 cm., and the internal diameter is 3·4 cm. Find the area of the top of the ring.

CHAPTER III

1. How many c.c. are in (1) a litre; (2) a cubic metre; (3) a cubic millimetre? How many litres are in (1) a cubic metre; (2) a c.c.?

2. How many cubes 2 cm. edge can be cut from a cube 16 cm. edge?

3. What is meant by capacity? How would you find the total capacity of a burette?

4. How would you find the volume of each of the following:—(1) a needle; (2) a broken brick; (3) a grain of wheat; (4) a wood bobbin?

5. A thread is tied to a piece of metal, which is then lowered into a jar of water and lifted out again. Is there any way of finding how much water has been lifted out with the metal?

6. A litre flask is filled with small lead pellets. How could you get the volume of the pellets and the approximate number?

7. Can you find the volume of a stone and of a sponge by the same method? If not, how can you find the volume of the sponge?

8. Coal is stored in a rectangular stack 40 yards long, 20 yards broad, and 20 feet high. How many cubic feet of coal are in the stack?

9. A box is found, by measurement, to be 16·17 cm. long, 12·25 cm. broad, and 6·07 cm. high (inside measurement). Find its capacity as accurately as possible.

10. A cistern is 6 feet long and 4 feet wide. What is its depth if it holds 30 cubic feet of water?

11. A street 60 feet wide and 100 yards long was covered with tar 1 inch thick. Find how much tar was used.

12. A sloping stack of coal is built on a foundation of 12 yards square, and rises to a point 12 feet above the foundation. How many cubic feet of coal are in the stack?

13. Find the volume of a lead pencil, diameter 0·82 cm., length 20·00 cm. If the thickness of the lead is 1·5 mm., find the volume of the wood.

14. A new grindstone is 4 feet 6 inches in diameter and 10 inches thick. At the end of a year it is 2 feet 2 inches in diameter and 9 inches thick. What fraction of the grindstone has been worn away?

15. A flat ring has external diameter 20·6 cm., internal diameter 10·6 cm., and thickness 0·5 cm. Find the total surface area and volume.

16. A silk hat is cylindrical. The diameter is 7 inches, and height 6·5 inches. If the part of a man's head inside the hat is taken as a hemisphere, how much air space is there in the hat above the head?

17. A conical paper bag, 2 inches diameter at the opening and 2 inches deep, when filled with sweets is sold for 2d. Another conical bag, 1 inch diameter and 4 inches deep, is also sold for 2d. Which is the better bargain?

18. The volume of an entangled piece of wire is 20·5 c.c. The diameter is 0·02 cm. Find the length.

19. The side of a square sheet of metal is 5·82 cm. The volume of the sheet is 0·4 c.c. What is the thickness?

20. Two metal balls are of radii 3 inches and 4 inches respectively. They are melted and recast into one ball. Find the volume of the new ball. Is the surface area of the new ball as great as the sum of the surface areas of the two old balls?

21. A glass tube is 2 metres long. The external diameter is 1·00 cm. and the internal diameter is 0·75 cm. Find the volume of the glass.

CHAPTER IV

1. What is the mass of a litre of water? Find the mass of the water in a cistern 50 cm. long, 20 cm. broad, and 8·5 cm. deep.

2. A bottle when full of water weighs 123·4 gm. Find its capacity if the empty bottle weighs 23·4 gm.

3. A bottle when full holds 123·4 gm. of water. Find its capacity.

4. A bottle when empty weighs 23·46 gm., and when full of water weighs 143·29 gm. Find the capacity of the bottle.

5. A tube weighs 16·25 gm.; when full of water it weighs 55·72 gm. The length of the tube is 10·12 cm. Find its diameter.

6. A pint of water weighs a pound and a quarter. Find the mass of a gallon of mercury (Relative Density = 13·6).

7. A circle of paper weighs 0·854 gm.; a square of the same paper, side 4 cm., weighs 0·168 gm. Find the area of the circle and its diameter.

8. The Relative Density of copper is 8·8 gm., while that of brass is about half a gm. less. Examine the accuracy of this statement.

9. A cube of metal, 2·2 cm edge, weighs 99·99 gm. Find the Relative Density.

10. Find the mass of a brass ball, 3·6 cm. diameter (Relative Density = 8·4).

11. An empty bottle weighs 16·216 gm.; full of water it weighs 60·178 gm., full of a liquid it weighs 72·194 gm. Find the Relative Density of the liquid.

12. A solid weighs 18·19 gm. in air, 13·27 gm. in water, and 14·92 gm. in a liquid. Find (1) the Volume of the solid, (2) Relative Density of the solid, (3) Relative Density of the liquid.

13. A solid weighing 25·28 gm. is dropped into a can of 25 c.c. capacity, full of water. 10·27 gm. of water remain in the can. Find the Relative Density of the solid.

14. A ball of metal 2·22 cm. diameter weighs 1 pound. Find the mass of a ball of the same metal the diameter being 4·44 cm.

15. A pipette holds 23·87 gm. of a liquid whose Relative Density is 1·06. What is the capacity of the pipette? How many c.c. of alcohol (Relative Density = 0·82) will the pipette hold?

16. A density bottle weighs, when empty, 10·178 gm., and when

full of water 40·253 gm.; when some powder is placed in the empty bottle the mass of the bottle + powder is 42·184 gm.; when the bottle is then filled up with water the mass of the bottle + powder + water = 65·245 gm. Find the Relative Density of the powder.

17. A cube of metal, 2 cm. edge, is attached to a spring balance and lowered into water. The reading on the balance is 56 gm. What is the mass of the metal?

18. A piece weighing 20 gm. is cut from a rod of brass 1 cm. in diameter. What is the length of the piece? (Relative Density of brass = 8·4.)

19. A rod of wood (Relative Density = 0·6) is placed upright in water. Will it float? If so, what fraction of it will be above the surface?

20. A prism of wood, 10 cm. by 6 cm. by 4 cm., floats in water so that one-fourth is above the surface. Find the mass of the wood and its Relative Density.

21. The following are the results of an experiment with Nicholson's Hydrometer:—

Weights to sink to mark = 10·254 gm.; weights to sink to mark when solid is in top pan = 4·316 gm.; weights to sink to mark when solid is in bottom pan = 6·058 gm. Find the Relative Density of the solid.

CHAPTER V

1. The height of the column of water in Hare's Apparatus is 22·2 cm. and of a liquid 18·8 cm. Is the liquid more or less dense than water? Give your reasons. Find the Relative Density of the liquid.

2. The heights of the columns of liquids in Hare's Apparatus are 20·5 cm. and 25·0 cm. respectively. The Relative Density of the heavier liquid is 1·42, what is the Relative Density of the other?

3. A barometer tube is 0·5 inches in diameter, and has a circular section. The barometric height is 29·2 inches. Find the mass of the mercury (Relative Density of mercury = 13·6, and a cubic foot of water weighs 1000 ounces), and so find the pressure of the atmosphere per square inch.

4. The following are the results got with a Boyle's Tube :—

Volume :	20·0 c.c.,	18·6 c.c.,	15·4 c.c.,	10·2 c.c.	6·9 c.c.
Pressure :	76·0 cm.,	81·8 cm.,	98·5 cm.		220·0 cm.

Draw a graph of the results, and so find the missing number.

5. A mercury barometer stands at 29·8 inches. Another barometer with a different liquid is 29·8 feet high. Find the Relative Density of the liquid.

6. A boy holds his finger tightly over one end of a narrow glass tube, and sucks at the other end. He finds that the tube sticks to his lip. Why? What happens when he tries to remove his finger from the end of the tube?

7. The pressure of the atmosphere is about 15 pounds per square inch. How has this been found?

TABLES

LENGTH

1 Inch = Centimetres
1 Metre = Inches
Diameter of Circle = (times) Radius
Circumference of Circle = (times) Diameter
,, ,, = (times) Radius

AREA (Formulæ)

Area of Square = $(S)^2$
,, Rectangle = (H X BREADTH)
,, Parallelogram = (PHx ")
,, Triangle = $\frac{\text{PHx "}}{2}$
,, Circle =
,, Surface of Cylinder =
,, Surface of Cone =

VOLUME (Formulæ)

Volume of Cube =
,, Square Prism =
,, Rectangular Prism =
,, Triangular Prism =
,, Square Pyramid =
,, Rectangular Pyramid =
,, Triangular Pyramid =
,, Cylinder =
,, Cone =
,, Circular Anchor Ring =

Relative Density of Solids

Solid	First Method	Second Method	Third Method	Fourth Method	Average

Relative Density of Liquids

Liquid	First Method	Second Method				Average

Relative Density of Gases

Gas	Relative Density

Mass of 1 litre of Air =

Pressure of Atmosphere

Normal Pressure of Atmosphere · inches of mercury
” ” ” = millimetres of mercury
” ” ” = lbs. per square foot
” ” ” = gm. per sq. cm.

Boyle's Law:

Heat

Coefficient of Expansion of Solids

Solid	Linea	Surface	Cubic

Coefficient of Expansion of Liquids and Gases

Liquid	Coefficient	Gas	Coefficient

Melting Points of Solids

Solid	Temperature

Boiling Points of Liquids

Liquid	Temperature

Charles's Law :

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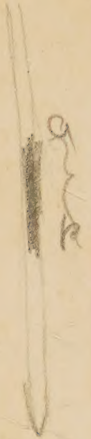

Press = atmos + aB

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